

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

IPG PHOTONICS CORPORATION
Petitioner

v.

TRUMPF LASER UND SYSTEMTECHNIK GMBH
Patent Owner

Case No. IPR2026-00251
U.S. Patent No. 12,240,054

**DECLARATION OF LIANG DONG, PH.D.
UNDER 37 C.F.R. § 1.68 IN SUPPORT OF PETITION
FOR *INTER PARTES* REVIEW**

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Declaration of Dr. Liang Dong
U.S. Patent No. 12,240,054

LISTING OF CLAIMS

[1Pre] A system for generating a laser beam with different beam profile characteristics, the system comprising:

[1A] a multi-clad fiber having an inner fiber core and at least one outer ring core; and

[1B] a first optical fiber configured to guide a first input laser beam to the multi-clad fiber; and

[1C] a second optical fiber configured to guide a second input laser beam to the multi-clad fiber,

[1D] wherein the system is configured to couple at least one of: the first input laser beam at least into the inner fiber core of the multi-clad fiber, or the second input laser beam at least into the at least one outer ring core of the multi-clad fiber.

[2] The system of claim 1, wherein the system is configured to couple the first input laser beam only into the inner fiber core of the multi-clad fiber.

[3] The system of claim 1, wherein the system is configured to couple the second input laser beam only into the at least one outer ring core of the multi-clad fiber.

[4A] The system of claim 1, wherein the multi-clad fiber comprises one or more claddings respectively around the inner fiber core and the at least one outer ring core, and

[4B] wherein the system is configured such that no laser beam is coupled into the one or more claddings.

[5Pre] The system of claim 1, wherein the multi-clad fiber is configured to have at least one of:

[5A] the inner fiber core with a diameter of no greater than 200 μm ,

[5B] the at least one outer ring core with a diameter of no greater than 600 μm , or

[5C] an inner cladding with a thickness of no greater than 10 μm , the inner cladding being between the inner fiber core and the at least one outer ring core.

[6] The system of claim 1, wherein the multi-clad fiber comprises the inner fiber core with a refractive index n_1 , a first cladding with a refractive index n_2 , and an outer ring core with a refractive index n_3 , and the first cladding surrounds the inner fiber core and is between the inner fiber core and the outer ring core, and wherein $n_1 = n_3$ and $n_1 > n_2$.

[7] The system of claim 6, wherein the multi-clad fiber further comprises a second cladding surrounding the outer ring core, and wherein a refractive index n_4 of the second cladding is identical to the refractive index of the first cladding n_2 .

[8] The system of claim 1, wherein the multi-clad fiber comprises two or more outer ring cores, and the system is configured to couple two or more corresponding input laser beams into the two or more outer ring cores.

[9] The system of claim 1, wherein the system is configured to generate an output laser beam with a power of at least 1 kW.

[10Pre] The system of claim 1, further comprising a switchable device coupled between the first and second optical fibers and the multi-clad fiber,

[10A] wherein the switchable device is configured to electively couple the first input laser beam at least into the inner fiber core of the multi-clad fiber and the second input laser beam at least into the at least one outer ring core of the multi-clad fiber.

[11Pre] A method of generating a laser beam with different beam profile characteristics, the method comprising:

[11A] guiding a first input laser beam by a first optical fiber to a fiber end of a multi-clad fiber, wherein the multi-clad fiber has an inner fiber core and at least one outer ring core;

[11B] guiding a second input laser beam by a second optical fiber to the fiber end of the multi-clad fiber;

[11C] coupling the first input laser beam and the second input laser beam into the fiber end of the multi-clad fiber, comprising at least one of:

[11D] coupling the first input laser beam at least into the inner fiber core of the multi-clad fiber, or

[11E] coupling the second input laser beam at least into the at least one outer ring core of the multi-clad fiber; and

[11F] generating an output laser beam by interaction of the first input laser beam and the second input laser beam with the multi-clad fiber, wherein a beam profile characteristic of the output laser beam differs depending upon the coupling of the first input laser beam and the second input laser beam into the fiber end of the multi-clad fiber.

[12Pre] The method of claim 11, wherein coupling the first input laser beam at least into the inner fiber core of the multi-clad fiber comprises:

[12A] coupling the first input laser beam only into the inner fiber core of the multi-clad fiber.

[13Pre] The method of claim 11, wherein coupling the second input laser beam at least into the at least one outer ring core of the multi-clad fiber comprises:

[13A] coupling the second input laser beam only into the at least one outer ring core of the multi-clad fiber.

[14Pre] The method of claim 11, wherein the multi-clad fiber comprises one or more claddings respectively around the inner fiber core and the at least one outer ring core, and

[14A] wherein coupling the first input laser beam and the second input laser beam into the fiber end of the multi-clad fiber comprises:

[14B] coupling no laser beam into the one or more claddings.

[15Pre] The method of claim 11, wherein the multi-clad fiber comprises an inner cladding between the inner fiber core and the at least one outer ring core, and wherein the multi-clad fiber is configured to have at least one of:

[15A] the inner fiber core with a diameter of no greater than 200 μm ,

[15B] the at least one outer ring core with a diameter of no greater than 600 μm , or

[15C] the inner cladding with a thickness of no greater than 10 μm .

[16] The method of claim 11, wherein the multi-clad fiber comprises the inner fiber core with a refractive index n_1 , a first cladding with a refractive index n_2 , and an outer ring core with refractive index n_3 , and the first cladding surrounds the inner fiber core and is between the inner fiber core and the outer ring core, and wherein $n_1=n_3$ and $n_1>n_2$.

[17] The method of claim 16, wherein the multi-clad fiber further comprises a second cladding surrounding the outer ring core, and wherein a refractive index n_4 of the second cladding is identical to the refractive index of the first cladding n_2

[18] The method of claim 11, wherein the multi-clad fiber comprises two or more outer ring cores, and the method comprises: coupling two or more corresponding input laser beams into the two or more outer ring cores.

[19] The method of claim 11, wherein the output laser beam has a power of at least 1 kW.

[20] The method of claim 11, wherein coupling the first input laser beam and the second input laser beam into the fiber end of the multi-clad fiber comprises: electively coupling, by a switchable device coupled between the first and second optical fibers and the fiber end of the multi-clad fiber, one of the first input laser beam at least into the inner fiber core of the multi-clad fiber and the second input laser beam at least into the at least one outer ring core of the multi-clad fiber.

I. INTRODUCTION

1. My name is Liang Dong.
2. I received a B.S. degree in Electronics from Harbin Institute of Technology in 1985. I received an M.S. in Telecommunications and Digital Electronics from the University of Manchester Institute of Science and Technology in 1987. I received a Ph.D. in Fiber Optics from the University of Southampton in 1992.
3. After obtaining my Ph.D. in 1992, I was a Research Fellow at the University of Southampton from 1992-1998, where I conducted research on silica optical fiber materials, fabrications, and devices.
4. From 1998-2000 I worked as a Senior Scientist/Project Manager at Corning Inc., where I developed specialty optical fibers and optical fiber Bragg gratings.
5. From 2000-2001 I was a Technical Manager at Corvis Corporation, where I managed efforts to develop optical fiber components based on photosensitive optical fibers.
6. From 2001-2003 I was the Founder of Attolight Inc. From 2002-2003 I was a Research Director at Lightwaves2020 Inc., where I directed research and development efforts on optical fiber components and subsystems for telecommunications.

7. From 2003-2010 I was a Senior Technical Manager at IMRA America Inc., where I directed research and development of specialty optical fibers for optical fiber lasers.

8. From 2010-2017 I was an Associate Professor at Clemson University. Since 2017 I have been a Professor at Clemson University, where I conduct research on advanced optical fibers for high-power fiber lasers and power-scaling of high-power fiber lasers.

9. I have nearly four decades of extensive experience working on and with fiber optic lasers.

10. I have authored over 350 publications in peer-reviewed academic journals, transactions, and books.

11. I am a named inventor in 28 issued U.S. Patents.

12. I am a fellow of multiple societies, including the IEEE, SPIE, and Optica.

13. A copy of my curriculum vitae (“CV”) is attached as Appendix A.

14. I am familiar with the technology of U.S. Patent No. 12,240,054 (the “’054 Patent”).

15. I am familiar with the knowledge and capabilities of a person of ordinary skill in the art at the time of the priority date of the ’054 Patent – April 8, 2010.

16. I understand that the '054 Patent was filed on November 6, 2023, as U.S. Patent Application No. 18/387,089. I understand that this application claims priority to numerous U.S. Patent Applications dating back to PCT EP/2011/055484, which claims foreign priority to DE 10 2010 003 750, which was filed April 8, 2010.

17. I have reviewed the following references in preparing this declaration, all of which I understand to be prior art to the '054 Patent:

- a. E.P. Patent No. 1,284,672 (“Neuberger”) (EX1004), which first published December 27, 2006.
- b. U.S. Patent No. 6,160,943 (“Davis”) (EX1005), which first published December 12, 2000.
- c. WO Patent Application No. 2006/021609 (“Kalle”) (EX1006), which first published March 2, 2006.
- d. U.S. Patent No. 4,000,416 (“Goell”) (EX1007), which first published December 28, 1976.
- e. U.S. Patent No. 5,897,551 (“Everett”) (EX1008), which first published April 27, 1999.
- f. 510(k) Summary FDA Approval of StrateFire™ Reusable Optical Fiber (EX1009), which first published June 5, 1997.
- g. U.S. Patent Application Publication 2008/0086118 (“Lai”) (EX1010), which first published April 10, 2008.

- h. Optical Communications Essentials by Gerd Keiser (“Keiser”) (EX1011), which first published July 28, 2003.
- i. U.S. Patent No. 4,465,335 (“Eppes”) (EX1012), which first published August 14, 1984.
- j. E.P. Patent No. 0,362,466 (“Hessel”) (EX1013), which first published April 11, 1990.

18. I have considered the following exhibits listed below in preparing this Declaration. In addition, I have reviewed and considered all other documents mentioned in my Declaration. My opinions are based on my personal knowledge of these documents as viewed from the lens of a person of ordinary skill in the art, which I am familiar with based on my technical education, training, and experience in the field.

Exhibit No.	DESCRIPTION
1001	U.S. Patent No. 12,240,054 (“The ’054 Patent”)
1003	File History of U.S. Patent No. 12,240,054
1004	E.P. Patent No. 1,284,672 (“Neuberger”)
1005	U.S. Patent No. 6,160,943 (“Davis”)
1006	WO2006/021609 (“Kalle”)
1007	U.S. Patent No. 4,000,416 (“Goell”)
1008	U.S. Patent No. 5,897,551 (“Everett”)
1009	510(k) Summary FDA Approval of StrateFire™ Reusable Optical Fiber
1010	U.S. Patent Application Publication 2008/0086118 (“Lai”)
1011	Optical Communications Essentials by Gerd Keiser (“Keiser”)
1012	U.S. Patent No. 4,465,335 (“Eppes”)
1013	Certified Translation of E.P. Patent No. 0,362,466 (“Hessel”)

19. I have been retained to serve as an expert for IPG Photonics in the field of fiber optic lasers.

20. I am being compensated for my work in this matter at my standard hourly rate of \$400/hour. I am also being reimbursed for reasonable and customary expenses associated with my work and comments testimony in this proceeding. My compensation is not contingent on the outcome of this matter or the specifics of my testimony.

21. I do not have any financial interest in the outcome of this case nor do I have any financial interest in IPG Photonics.

22. I have been asked to provide my opinions regarding whether the subject matter of claims 1-20 (“the Challenged Claims”) of the ’054 Patent would have been obvious to a person having ordinary skill in the art (“POSITA”) at the time of the alleged invention, in light of the prior art. It is my opinion that the Challenged Claims would have been obvious to a POSITA.

II. RELEVANT LAW

23. I am not an attorney. In preparing and expressing my opinions and considering the subject matter of the ’054 Patent, I am relying on certain basic legal principles that Counsel for IPG Photonics has explained to me. My understanding of the relevant law is as follows:

A. Level Of Ordinary Skill In The Art

24. I have been informed and understand that a patent should be analyzed within the framework of a person of ordinary skill in the art (“POSITA”), which is a hypothetical person who would have been knowledgeable about the prior art that was accessible at the time of the priority date of the patent. Here, the ’054 Patent has an earliest priority date of April 8, 2010.

25. I have also been informed that factors considered in determining a POSITA include: (1) the problems encountered in the art; (2) the prior art solutions to the problems encountered in the art; (3) the rapidity of innovation; (4) the sophistication of the technology; and (5) the education level of active workers in the field. I understand that these factors need not all be taken into account for the analysis and that one or more of these factors may control.

26. I have been informed that a POSITA is a person of ordinary creativity. A POSITA is not an automaton and would be able to consider and put together teachings from multiple prior art references.

B. Claim Construction

27. I have been informed that to determine the meaning of the terms in the claims of the ’054 Patent for the purposes of the *inter partes review*, one should generally use the ordinary and customary meaning as understood by a POSITA at

the time of the claimed priority date, taking into consideration the claim language and patent specification.

28. I have been informed that a patentee can include a definition of a claim term in the specification. In such instances, I understand that the claim should generally be interpreted according to that definition provided in the patent.

29. I have been informed that a patent's claims, specification, and file history (EX1003) should be analyzed to arrive at the proper interpretation of a claim term.

C. Anticipation

30. I understand a patent claim is considered "anticipated" by the prior art when each and every limitation of the claims is found within a single prior art reference either expressly or inherently. I understand this means the prior art reference does not need to match the claim word for word. I understand that a reference anticipates a patent if a POSITA could make and use the technology in the patent after reviewing this single reference.

31. I understand that when a claim limitation covers a range, that limitation can be anticipated by a prior art reference that teaches either a single value or a smaller range that is still within the claimed range. I further understand that a range disclosed in the prior art that overlaps with a claimed range may anticipate that claimed range if the patent does not claim that the range is critical.

32. I further understand that figures can teach a claim limitation if they clearly show the structure that is claimed.

D. Obviousness

33. I have been informed that a claim can be found unpatentable based on obviousness. I understand that a claim is obvious if a single prior art reference or a combination of prior art references teaches or suggests the claims. I understand that a POSITA must be motivated to combine the references with a reasonable expectation of success. Therefore, I understand that the challenged claims of the patent should be read from the point of view of a POSITA.

34. I have been informed that in an *inter partes* review, the Patent Trial and Appeal Board (the “Board”) evaluates obviousness of a claim under a preponderance of the evidence standard, which means that the Board determines that a claim is unpatentable for being obvious when the claim is more likely obvious than nonobvious.

35. I have been informed that the Supreme Court has indicated that obviousness may be found if:

- There is some teaching, suggestion, or motivation in the prior art that would have led a POSITA to combine prior art reference teachings or modify the prior art to arrive at the claims;

- The modification is a combination of prior art elements according to known methods to yield predictable results;
- The combination of prior art is a simple substitution of one known element for another to obtain predictable results;
- The combination of prior art elements is an application of a known technique to a known device (or method) ready for improvement to yield predictable results;
- The changed element(s) represent one of a finite number of identified, predictable solutions, and a POSITA would have a reasonable expectation of success that such modification would work.

36. I understand when determining obviousness, one cannot use the benefit of hindsight derived from the patent being considered.

III. SUMMARY OF OPINIONS

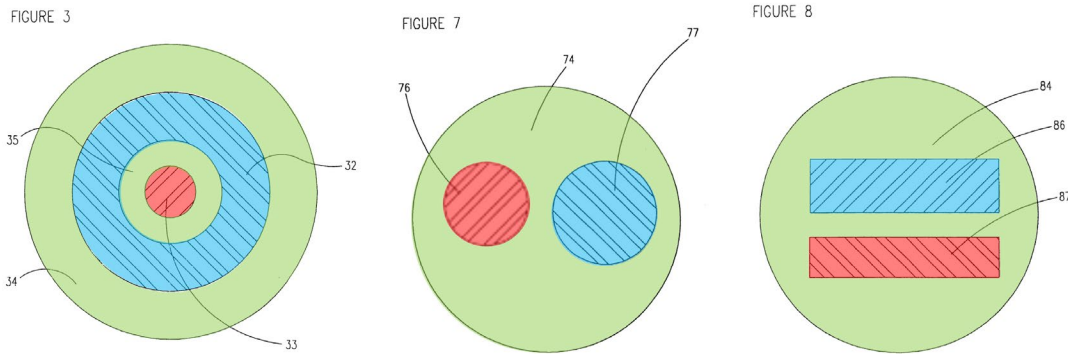
37. For the reasons explained below, I conclude that claims 1-20 of the '054 Patent are either anticipated or rendered obvious by the prior art.

Ground	Claims	Statutory Ground	References
I	1-8, 10-18, 20	35 U.S.C. §103	Neuberger, Davis
II	5, 15	35 U.S.C. §103	Neuberger, Davis, Kalle
III	6-8, 16-18	35 U.S.C. §103	Neuberger, Davis, Goell
IV	9-10, 19-20	35 U.S.C. §103	Neuberger, Davis, Lai

IV. TECHNOLOGY OVERVIEW

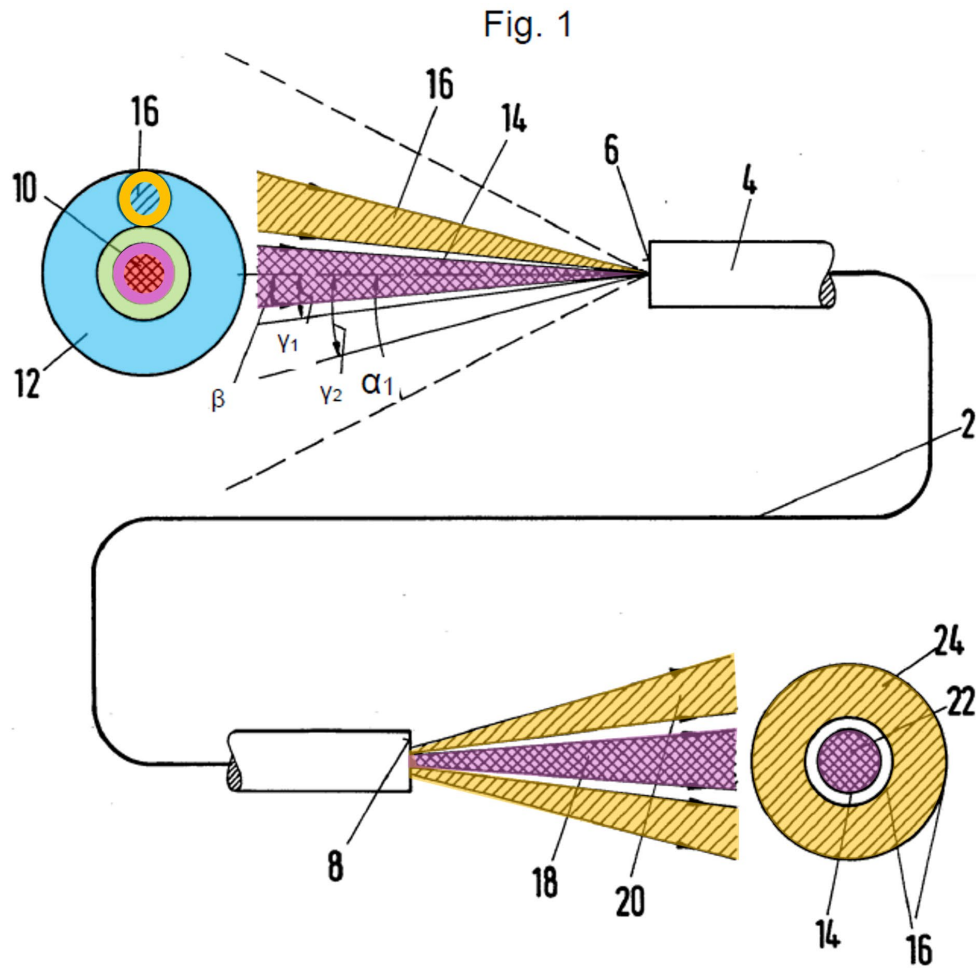
38. Optical fiber communications systems are a cornerstone of the modern Information Age. First developed in the 1970s, today's fiber optic systems build upon over 100 years of research on the transmission of electromagnetic waves. EX1011, 2. Fiber optic cables typically feature cores surrounded by claddings. EX1011, 23, 47, 338, 343. These structures are often made by standard techniques such as fiber pulling and chemical vapor deposition. EX1007, 1:62-67. EX1011, 24, 335-336. EX1012, 2:29-31. The cores enable signal transmission while the claddings serve to confine light within the core and to minimize crosstalk between signals traveling through different cores. EX1007, 1:40-42, 2:49-52. EX1012, 4:22-24. It is therefore essential that the cladding materials have a lower refractive index than the core materials. EX1011, 37, 47. The cores are usually made of higher refractive index material, such as germanium-doped silica, while the claddings usually are made of lower refractive index material, such as boron-doped silica. EX1007, 1:67-2:2. EX1011, 47.

39. Fiber optic cables can have a single core, which transmits a single signal, or multiple cores to transmit multiple signals. EX1004, [0017]. EX1007, 4:11-19. EX1011, 23, 47. The cores may be arranged either concentrically or non-concentrically, as shown in the Figure below. EX1004, [0023]-[0024].



EX1004, FIGS. 3, 7, 8;

40. The shape of the core influences the properties of the output beam. For instance, a beam coupled to a circular core may have a circular output beam profile. Meanwhile, a beam coupled to a ring-shaped core may have a ring-shaped output profile. EX1013, 3:39-50, 4:4-12 (“[T]he central light beam 14 emerges at the distal end of the guide with an axially symmetric output-angle range 18 corresponding to the coupling-angle range 10, while the oblique beam 16 exits the optical waveguide 2 with an output-angle range 20 corresponding to the coupling-angle range 12, as a ring-shaped beam, spatially separated from the central light beam.”), Figures 1-5. To illustrate this, I have annotated Figure 1 of EX1013 (Hessel) below:

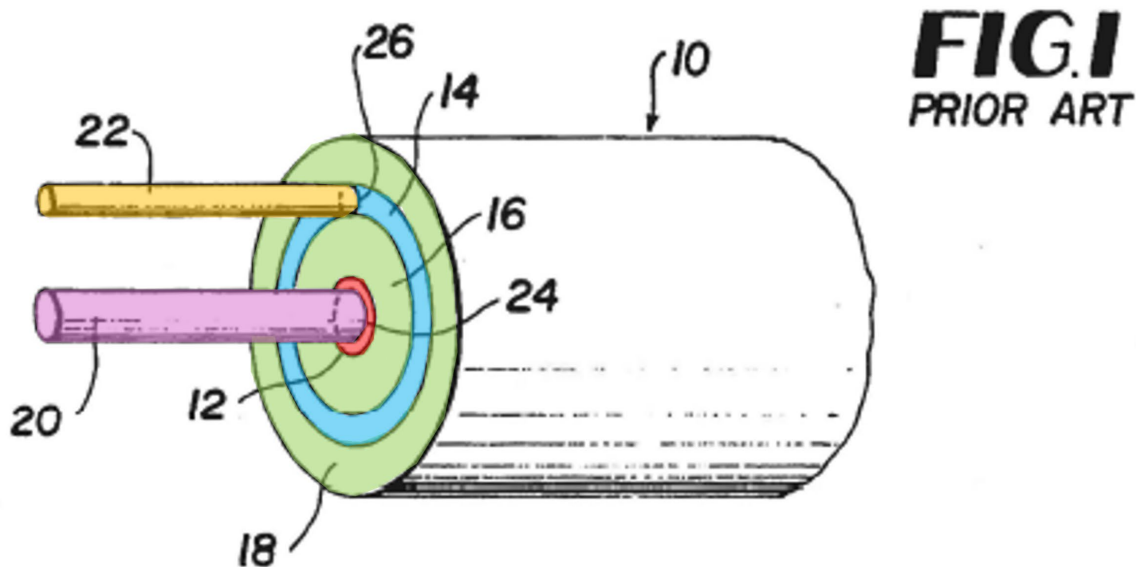


EX1013, FIG. 1.

41. The intensity of the output beam is inversely proportional to its size.

EX1011, 255. A smaller output beam will therefore have higher intensity than a larger output beam made using the same input.

42. There are several approaches to coupling, or guiding, an input signal into and through the cores of an output optical fiber. In some cases, single core optical fibers such as 20 and 22 can be aligned with cores 12 and 14 of the output fiber 10 and epoxied together, as depicted in the Figure below:



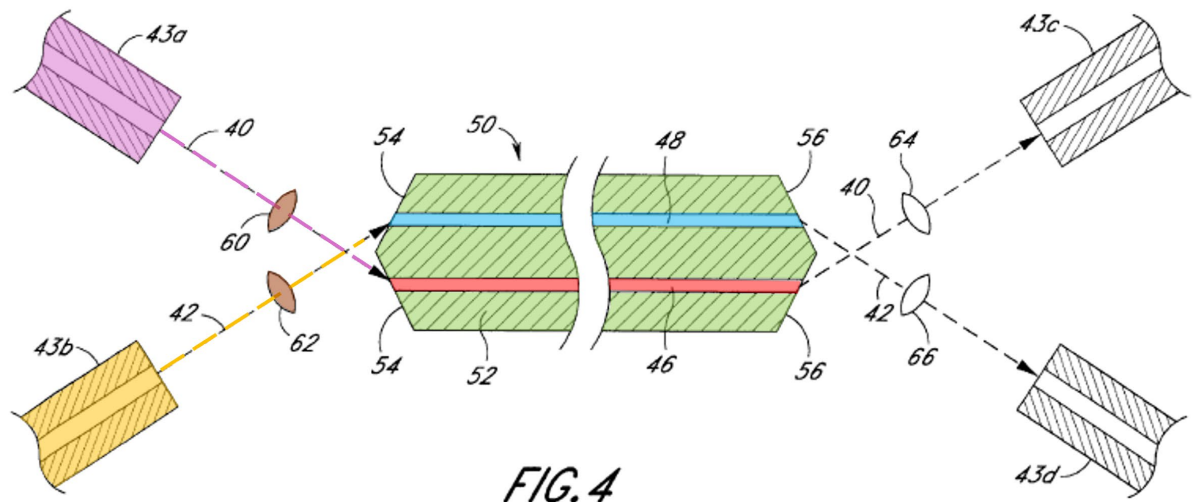
EX1012, FIG. 1

43. A signal from input fiber 20 then travels through core 12 of the output fiber 10 while a signal from input fiber 22 travels through the concentric core 14 of the output fiber 10. Each of the cores is surrounded by a layer of cladding, 16 of 18, that minimizes the crosstalk between the signals travelling through each of the cores 12 and 14.

44. To prevent light from leaking out of the cores, the epoxy that bonds the input fibers to the cores of the output fiber “must be optically clear and have an index of refraction which closely matches that of the core materials...” EX1012, 3:25-32. Additionally, an opaque stripping compound can be used to “absorb... extraneous

optical power that is not coupled into the [core] from the single core fibers...”).
EX1012, 3:32-40.

45. A second technique for coupling input signals to the multicore output fiber is to use optical elements like mirrors, lenses, or prisms to guide the signals into the cores of the output fiber, as in the figure I have annotated below. EX1005, 4:66-5:3, 5:42-45, 5:51-54, 6:20-25.



EX1005, FIG. 4.

46. In this schematic, the input optical fibers 43a and 43b are not directly joined to the output optical fiber 50. EX1005, 6:20-25. Instead, there is space between the optical fibers and lenses guide the input beams to the cores of the output fiber. EX1005, 4:66-5:3, 5:42-45, 5:51-54.

V. OVERVIEW OF THE '054 PATENT

A. Summary of the '054 Patent

47. I have reviewed the '054 Patent. *See* EX1001.

48. The '054 Patent is related to an optical fiber system that can generate various types of output beams. EX1001, Abstract. As shown in Figure 6, which I have annotated below, the '054 Patent features a multicore output fiber 10 that includes an inner fiber core 4, an outer fiber core 6, and two layers of cladding, 5 and 7, surrounding each of the cores. *See* EX1001, 9:17-39, 2:34-38 (“A double-clad fiber with two cores has an inner fiber core and cladding surrounding this fiber core that is as thin and low-refractive as possible. This is followed by a single outer ring core which is also surrounded by low-refractive second cladding.”).

49. A laser beam 61 from an input fiber 63 is coupled into the inner core 4 and a different laser beam 62 from a different input fiber 64 is coupled into the outer core 6. There is a switching device 65 between the input fibers 63 and 64 and the output fiber 10. The switching device 65 contains optical elements such as lenses, prisms, or mirrors that can switch the core into which the laser beams are coupled. The output fiber 10 generates an output beam 3 that has different properties depending on the core from which it was generated. For example, an output beam generated by the circular inner core 4 may have a smaller circular beam profile with higher intensity while an output beam generated by the ring-shaped outer core 6 may

have a larger ring-shaped beam profile with lower intensity. The different beam profiles are used in different applications such as cutting and welding. EX1001, 2:48-57. (“In material processing using laser beams, in particular using high power in the kW range, the ability to switch between these coupling variants makes it possible, for example, to choose between a comparatively good beam quality with a sharp focus as is required, for example, for a laser cutting process, and, in contrast, a ‘reduced’ beam quality with a ‘blurred’ focus with almost uniform intensity distribution in the beam cross-section, which is particularly suitable for welding processes.”).

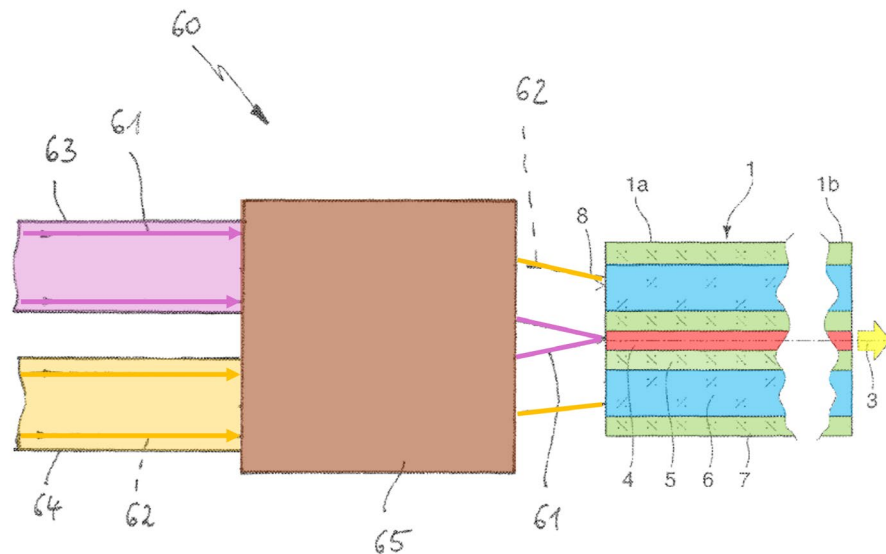


Fig. 6

EX1001, FIG. 6.

B. Summary of the Prosecution History of the '054 Patent

50. I have reviewed the file history of the '054 Patent, which I summarize below. *See* EX1003.

51. The application for the '054 Patent was filed on November 6, 2023 by Trumpf Laser und Systemtechnik (the "Applicant"). EX1003, 1. The original claims 1-27 were cancelled in a Preliminary Amendment. After that, the Claims 28-47 were examined. EX1003, 60-64. The Examiner rejected claims 28-33, 36, 38-43, and 46 on the grounds of non-statutory double patenting over U.S. Patent No. 10,281,656. EX1003, 169-180. The Applicant then filed a Terminal Disclaimer over that patent to overcome the rejection. EX1003, 184-191. The Examiner then allowed the claims, unamended. EX1003, 262-268.

C. Priority Date of the '054 Patent

52. I understand that a continuation may claim priority to multiple parent applications. I further understand that a claim in a continuation is entitled to the benefit of an earlier filing date of a parent only when all limitations of the claim, as arranged, are supported by the parent application.

53. I understand that the '054 Patent issued from U.S. Application No. 18/387,089 ("089 App.") filed November 6, 2023, which is a continuation of U.S. Application No. 17/552,455 ("455 App."), filed April 30, 2019, which is a divisional of U.S. Application No. 16/398,362 ("362 App."), filed April 30, 2019,

which is a continuation of U.S. Application No. 15/297,781 (“781 App.”), filed September 29, 2016, which is a continuation of U.S. Application No. 14/300,138 (“138 App.”), filed June 9, 2014, which is a continuation of U.S. Application No. 13/369,401 (“401 App.”), filed April 8, 2011, which is a National Stage Application of PCT EP/2011/055484, which claims foreign priority to a German patent DE 10 2010 003 750, filed April 8, 2010.

VI. LEVEL OF ORDINARY SKILL IN THE ART

54. As I noted above in Section II.A [Level Of Ordinary Skill In The Art], I have been informed by counsel that a patent and the prior art should be analyzed from the perspective of a POSITA.

55. A POSITA as of the earliest claimed filing date of the ’054 Patent (*i.e.*, April 8, 2010) would have had a bachelor’s degree in Electronics, Electrical Engineering, Telecommunications, Optical Engineering, Fiber Optics, or an equivalent field, and about 2-3 years of experience in the field of optics. I note that a higher level of education or specific skills in a relevant industry may make up for less experience, and vice versa.

56. I met and/or exceeded these requirements for a POSITA as of April 8, 2010, for at least the reasons I provided above in Section I [Introduction].

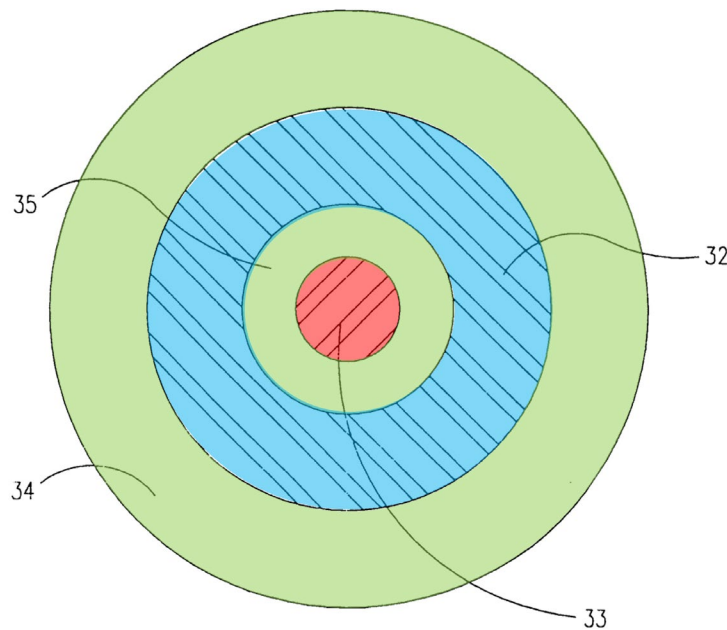
VII. OVERVIEW OF PRIMARY PRIOR ART REFERENCES

A. Neuberger

57. Neuberger describes “laser systems that transmit at least two wavelengths or power densities of light energy.” Neuberger uses a multicore optical fiber to generate either a higher intensity beam (useful for cutting tissue) and a lower intensity beam (useful for coagulating tissue). EX1004, [0001] (“The present invention relates to diode laser systems that transmit at least two wavelengths of light energy through a single step index fiber system having at least two core sections”), [0013] (“Still another object of the present invention is to provide a multiple core fiber which allows simultaneous transmission of both high power density radiation or high absorption wavelength that may be used for tissue cutting or ablating, and lower power density radiation that may be used for tissue coagulation and/or bio-stimulation.”). Neuberger’s output fiber transmits diode lasers and Nd:YAG lasers, which have many applications in the medical field. The patent explains that “[s]olid state lasers, such as the Nd:YAG, have primarily been employed to achieve the desired optical power and wavelength for medical procedures” while “diode lasers are cheap, small, and have lower power requirement.” EX1004, [0002] (“The present use of lasers in medical procedures and surgical applications is virtually unlimited. Solid state lasers, such as the Nd:YAG, have primarily been employed to achieve the desired optical power and

wavelength for medical procedures ...”). In Figure 3 (as I have annotated below) Neuberger provides an example of a multicore output fiber that features an **inner fiber core 33**, **inner cladding 35**, **outer fiber core 32**, and **outer cladding 34**. *See id.*, [0021]. (“FIG. 3 displays an embodiment of a side cut cross sectional view of an optical fiber... In this embodiment four concentric layers constitute the part of the optical fiber that transmits two wavelengths of radiation...”).

FIGURE 3



EX1004, FIG. 3.

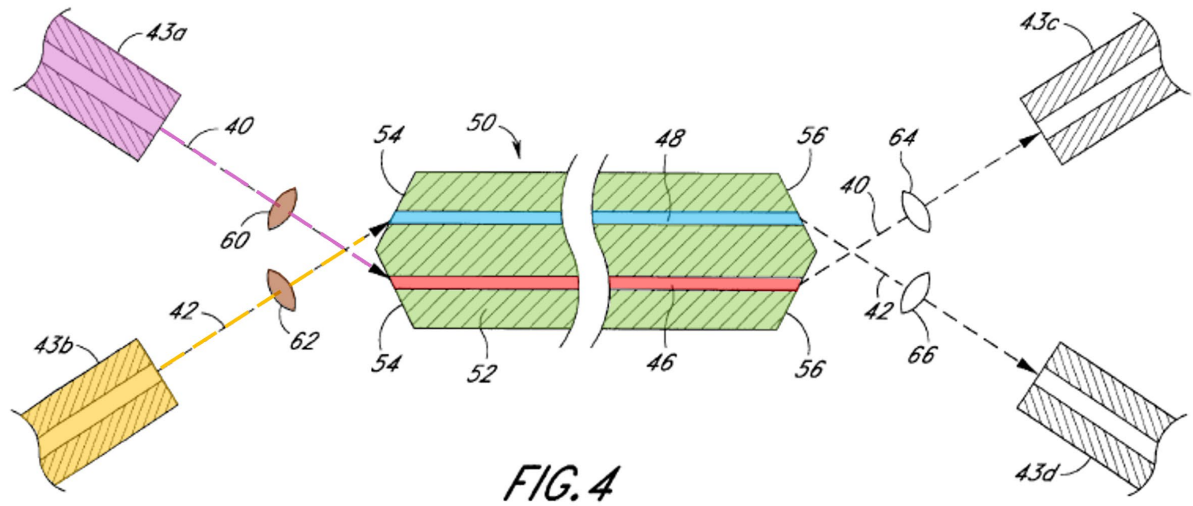
B. Davis

58. The Davis patent describes systems and methods for coupling laser beams into the different cores of a multicore output fiber. The multicore output fiber

of Davis features “a plurality of cores surrounded by a **cladding**.” EX1005, 2:65-67, claims 1-12. *See* EX1005, 1:6-7 (“The present invention relates to dual-core and multicore optical fibers, and in particular, to the simultaneous accessibility of multiple cores in the same fiber.”), 4:51-61 (“One embodiment of the invention is illustrated in FIG. 3A, in which an optical beam 40 from an optical source 44 (such as a laser diode, a Ti:Sapphire laser, a Nd:YAG laser, or the like) enters, via refraction, a **core** 46 of an optical fiber 50 (that includes a **second core** 48), in which the cores 46 and 48 are surrounded by a **cladding** 52. Alternatively, the optical source 44 may be remotely situated from the optical fiber 50 but optically connected to it using optical means such as a fiber optic link (not shown). The terms “optical” and “light” are used broadly herein to encompass both visible and invisible electromagnetic radiation.”). Davis additionally explains coupling “spatially separated light sources . . . into different cores of a multiple-core fiber.” EX1005, 2:59-61. The input light in Davis could be an Nd:YAG laser or a diode laser. EX1005, 4:51-66. Davis shows that single core optical fibers can be used as the input source to guide different laser beams into various cores of the output fiber. EX1005, 6:21-23 (“In this embodiment, however, all the inputs . . . involve the use of single-core fibers 43a-[b]...”), Figure 4.

59. In Figure 4 (as I have annotated below) Davis explains that single-core input fibers 43a and 43b **couple** two different input beams, 40 and 42, into two

different cores, 46 and 48, of a multicore optical output fiber 50. EX1005, 6:20-25. (“An embodiment similar to that shown in FIG. 3B is shown in FIG. 4. In this embodiment... all the inputs and outputs preferably involve the use of single-core fibers 43a-d, or, for example, integrated optical waveguides. Lenses 60 and 62 are used on the input side, and lenses 64 and 66 on the output side, of fiber 50.”). Davis explains that one may use lenses to electively couple the input beams into a specific core of the output fiber. The lenses are placed on movable stages so they can couple the input light into different cores. (“[O]ptical elements such as lenses 60 and 62 may be used to focus optical beams 40 and 42 onto individual cores 46 and 48.”). EX1005, 5:43-45, 5:58-60 (“[T]he term lens may refer to either one kind of lens or a combination of lenses. The lenses 60 and 62 must be close enough to the fiber 50 that the beams 40 and 42 can be efficiently coupled into the cores 46 and 48.”). (The lenses are “resting upon respective translation stages to control the alignment of the optical beams 40 and 42, which propagate along the optical paths within the cores 46 and 48.”). EX1005, 5:45-50.



EX1005, FIG. 4.

VIII. GROUNDS

A. Ground I: Neuberger In Combination With Davis Renders Obvious Claims 1-8, 10-18, And 20

1. Claim 1

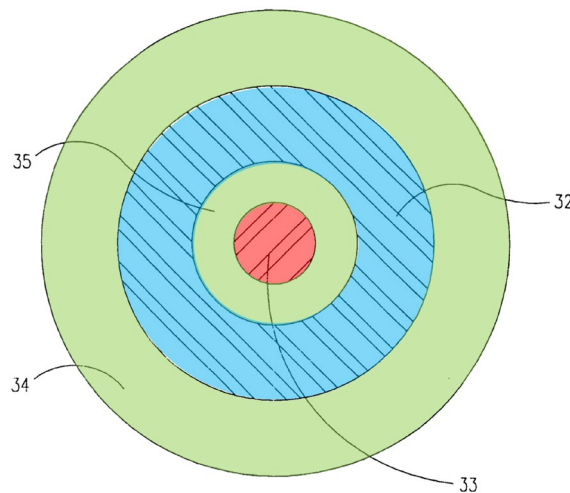
- a) [1Pre] A system for generating a laser beam with different beam profile characteristics, the system comprising:

60. The combination of Neuberger and Davis renders obvious [1Pre].

Neuberger describes “laser systems that transmit at least two wavelengths or power densities of light energy through a single step index fiber system having at least two core sections.” EX1004, [0001]. In Figure 3, which I have annotated below, Neuberger shows a concentric multicore output optical fiber that features an **inner**

fiber core 33, an outer fiber core 32, and two layers of cladding, 34 and 35. The inner cladding 34 is sandwiched between the inner fiber core 33 and the outer fiber core 32. The outer cladding 35 covers the outer fiber core 32.

FIGURE 3



EX1004, FIG. 3, [0021].

61. Neuberger's system "allows for efficient transmission of at least two power densities or at least two wavelengths." EX1004, [0011] ("it is therefore an object of the present invention to provide a medical diode laser system that allows for efficient transmission of at least two power densities or at least two wavelengths."); *see also id.*, [0013] ("Still another object of the present invention is to provide a multiple core fiber which allows simultaneous transmission of both high power density radiation or high absorption wavelength that may be used for tissue cutting or ablating, and lower power density radiation that may be used for tissue

coagulation and/or biostimulation”), [0017]-[0019] (“The present invention provides a device that allows for concurrent transmission of at least two wavelengths or at least two power densities which can for example simultaneously cut or vaporize and coagulate tissue... [T]he present invention is not limited to transmission of only two wavelengths or power densities. Additional concentric layers can be added to the fiber to transmit additional wavelengths... Outer core radiation 13 is used to coagulate tissue 11. Outer core radiation 13 is guided into and transmitted through outer core fiber 15, which encircles inner fiber core 16.”), [0021] (“Inner fiber core 33 transmits high power density radiation and is surrounded by inner cladding 35. Inner cladding 35 is surrounded by outer fiber core 32, which transmits the second wavelength radiation. Outer cladding 34 forms the fourth layer and surrounds outer fiber core 32.”), claims 1, 2, 5, and 6.

62. Neuberger’s output fiber can be used to produce output beams with different beam characteristics, just like the goal of the ’054 Patent. EX1004, [0004] (“Thus, depending on the desired effect of a medical laser, a *small or large* spot size is chosen.”). The inner core of the output fiber can produce a smaller output beam with high power density, which can be used to cut. EX1004, [0004]. The “[i]nner fiber core 33 transmits high power density radiation.” The outer core of the output fiber can produce a larger output beam with low power density, which can be used

to coagulate. EX1004, [0021]. The “outer fiber core 32 ... transmits a second wavelength radiation.” *Id.*

63. Since Neuberger’s system was made for surgical applications, the cutting and coagulation is performed on biological tissues. A beam transmitted through the inner core can be used to “cut or ablate tissue,” while a beam transmitted through the outer core can be used to “coagulate tissue.” *Id.*, [0002], [0004], [0018]-[0019]; *see also id.* [0014] (“Radiation of a suitable wavelength for tissue cutting or ablating is coupled into an inner fiber core to produce an output beam with sufficient power density for ablation. Radiation of a suitable wavelength for tissue coagulation is introduced into an outer fiber core to produce another output beam with a lower power density appropriate for coagulation”). This mode of operation is just like the ’054 Patent’s method of generating “different beam profile characteristics” for either cutting or welding with beams output by the inner core and the outer core, respectively. *See* EX1001, 2:44-57.

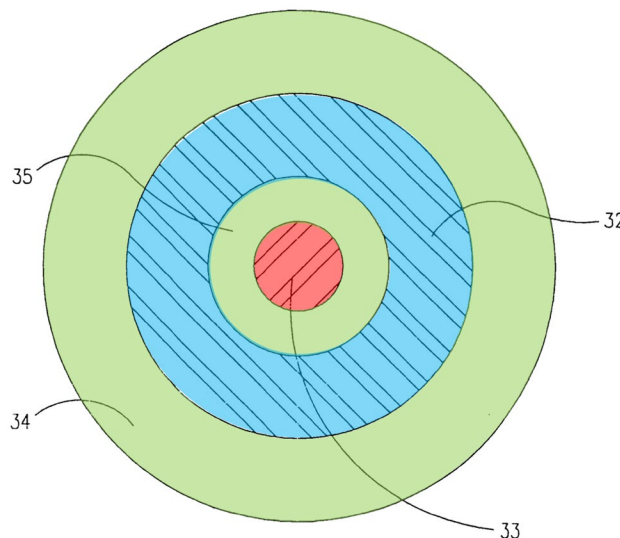
64. Neuberger uses either solid state lasers or diode lasers as the input beams. EX1004, [0002]. However, Neuberger does not explain how these input beams enter the multicore optical fiber. It was well-known that one could use single core fibers as sources for the input beams. This is explained by the Davis patent, as I discussed above in Section VII.B [Overview of Prior Art, Davis].

65. Even though Neuberger does not teach how to couple the incoming light into the cores of the output fiber, methods of doing so were well-known in the art long before the 2010 priority date of the '054 Patent. As I explained in Section VII.B [Overview of Prior Art], Davis shows that laser beams can be guided into the cores of the output fiber by single-core fibers and optical switching devices. *See* Section VII.B [Overview of Prior Art]; *see also* EX1005, Abstract, (“An optical fiber has two or more cores with respective faces on the fiber’s ends. The faces are preferably oriented so that optical radiation can be coupled into or out of the individual cores...”), 4:12-13 (“[A]n optical signal is refractively coupled into one of the cores of a multiple core optical fiber”), 5:51-58 (“The lenses 60 and 62 may be any type of focusing optical elements, such as Fresnel lenses, single optical lenses, doublets, triplets, or even transparent spheres placed or fixed at the input end and/or output end of fiber 50... As used herein, the term lens may refer to either one kind of lens or a combination of lenses.”), 6:20-23 (“An embodiment similar to that shown in FIG. 3B is shown in FIG. 4. In this embodiment, however, all the inputs and outputs preferably involve the use of single-core fibers 43a-d, or, for example, integrated optics waveguides.”). A POSITA would have had numerous reasons to use Davis’ coupling techniques with Neuberger’s output fiber with a reasonable expectation of success. *See* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

b) [1A] a multi-clad fiber having an **inner fiber core** and at least one **outer ring core**; and

66. Neuberger discloses [1A]. Neuberger provides an example of a multicore output fiber in Figure 3, which I have annotated below. The fiber includes an **inner fiber core 33** and **outer fiber core 32**. The **outer fiber core 32** is a **concentric ring**, which meets the requirement of an “**outer ring core**”. The fiber also includes multiple claddings—an **inner cladding 35** and an **outer cladding 34**, which makes it a “multi-clad fiber.” EX1004, Figure 3, [0013], [0021] (“[F]our *concentric* layers constitute the part of the optical fiber that transmits two wavelengths of radiation. **Inner fiber core 33** transmits high power density radiation and is surrounded by **inner cladding 35**. **Inner cladding 35** is surrounded by **outer fiber core 32**, which transmits the second wavelength radiation. **Outer cladding 34** forms the fourth layer and surrounds **outer fiber core 32**.”).

FIGURE 3



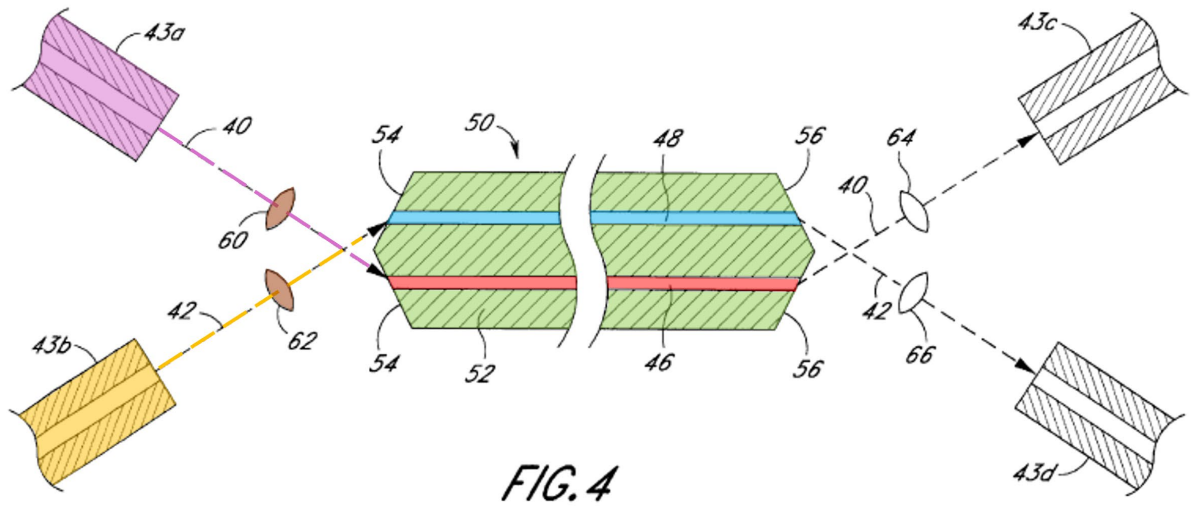
EX1004, FIG. 3.

- c) [1B] a first optical fiber configured to guide a first input laser beam to the multi-clad fiber; and
- [1C] a second optical fiber configured to guide a second input laser beam to the multi-clad fiber,
- [1D] wherein the system is configured to couple at least one of: the first input laser beam at least into the inner fiber core of the multi-clad fiber, or the second input laser beam at least into the at least one outer ring core of the multi-clad fiber.

67. Neuberger in combination with Davis renders obvious [1B]-[1D]. In Neuberger's system, a first laser beam is coupled to one core of the optical fiber and a second laser beam, which has a different power density, wavelength, or pulsing frequency from the first laser beam, is coupled to a second core of the optical fiber. EX1004, claim 2 ("at least two laser sources are transmitted with at least two different power densities."), claim 3 ("at least two laser sources operate at at least two different wavelengths."), claim 4 ("said radiation from a first source is pulsed and from a second source is a continuous wave."). These first and second input laser beams could be an Nd:YAG laser or a diode laser. EX1004, [0002] ("The present use of lasers in medical procedures and surgical applications is virtually unlimited. Solid state lasers, such as the Nd:YAG, have primarily been employed to achieve the desired optical power and wavelength of medical procedures...").

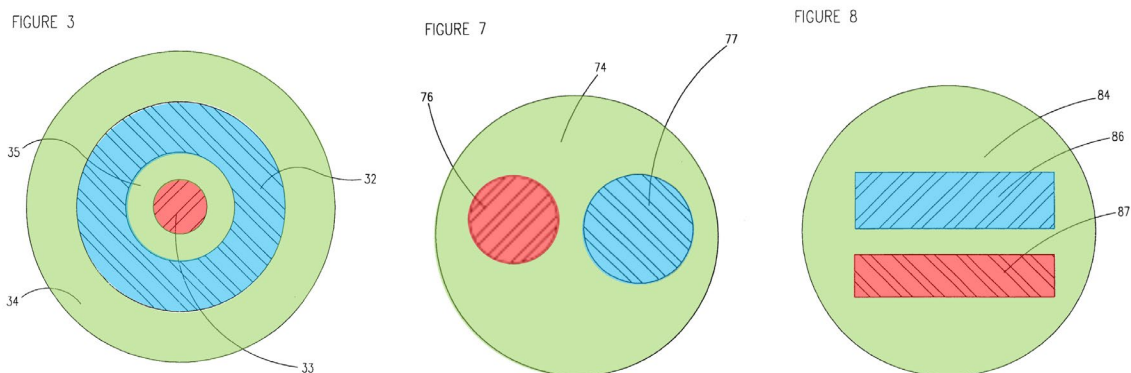
68. While Neuberger does not teach one how to input these laser beams into the multicore output fiber, it was well-known at the time to use a first optical fiber to **couple** and/or **guide** a first input laser beam into one core of the multicore output fiber, and to use a second optical fiber to **couple** and/or **guide** a second input laser beam to a different core of the multicore output fiber. In both cases, the input laser beam would be inserted at the fiber end of the multicore output fiber.

69. Figure 4 of Davis, which I have annotated below, demonstrates a first optical fiber 43a **couples** a first laser beam 40 to core 46 of the multicore fiber 50 and a second optical fiber 43b **couples** a second laser beam 42 to a second core 48 of the multicore fiber 50. The input beams 40 and 42 are **coupled** to the cores 46 and 48 by the lenses 60 and 62. See EX1005, 4:51-58 (“an optical beam 40 from an optical source 44 ... enters, via refraction, a core 46 of an optical fiber 50 (that includes a second core 48), in which the cores 46 and 48 are surrounded by a cladding 52... [t]he optical source 44 may be remotely situated from the optical fiber 50 ...”), 6:20-23. Davis, like Neuberger, says that the optical source may be “a laser diode, ... a Nd:YAG laser, or the like” EX1005, 4:51-56; *see also* EX1004, [0002] (“The present use of lasers in medical procedures and surgical applications is virtually unlimited. Solid state lasers, such as the Nd:YAG, have primarily been employed to achieve the desired optical power and wavelength of medical procedures...”



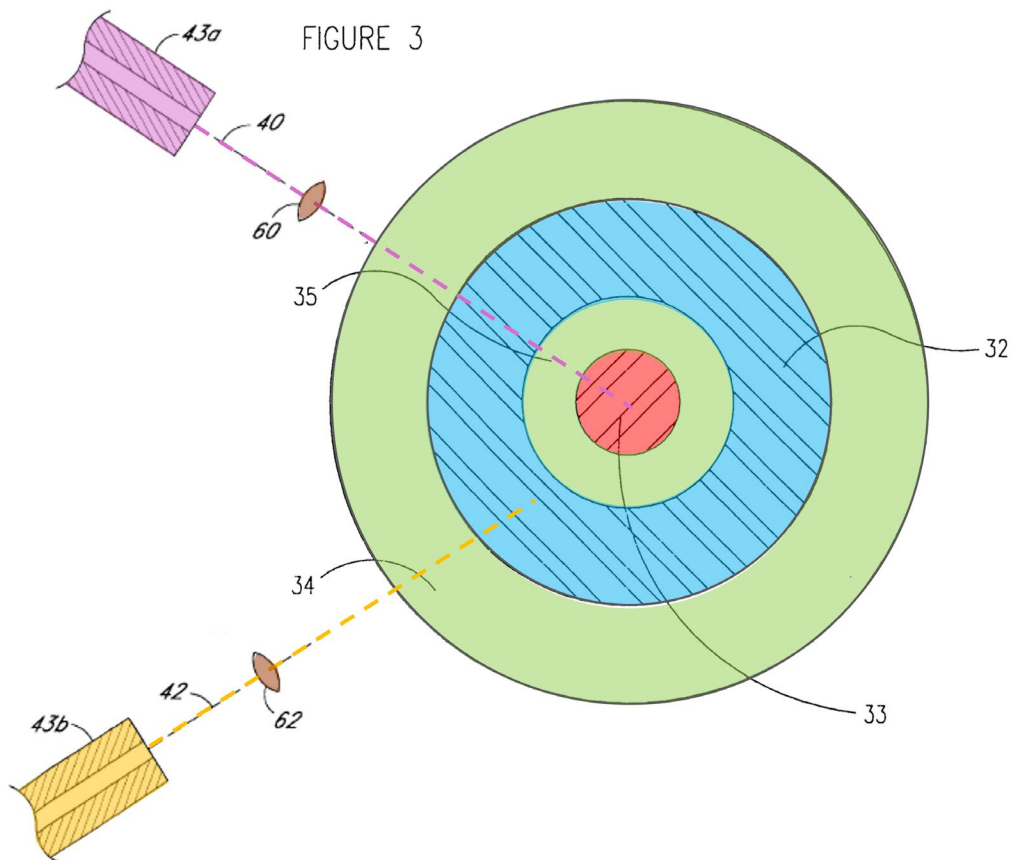
EX1005, FIG. 4.

70. While the cores in Davis' multicore output fiber are not concentric, it was known at the time that concentric and non-concentric cores were interchangeable. In fact, Neuberger explains that one could exchange the concentric and non-concentric cores with one another.



EX1004, FIGS. 3, 7, 8; *see also id.*, claims 9, 12, [0021], [0026].

71. A POSITA would have found it obvious to use Davis' coupling techniques with Neuberger's multicore output fiber. In the combination, Davis' first input laser beam 40 from first optical fiber 43a couples into Neuberger's inner core 33 and Davis' second input laser beam 42 from second optical fiber 43b couples into Neuberger's outer ring core 32, as I have shown below:



see EX1005, FIG. 4 and EX1004, FIG. 3.

2. Reasons To Combine Neuberger With Davis

72. There are many reasons a POSITA would think to use Davis' coupling technique with Neuberger's concentric multicore output fiber with a reasonable expectation of success.

73. *First*, the combination amounts to nothing more than combining prior art elements according to known methods. Each of the references teaches the same kind of system—multicore output fibers that transmit diode lasers and Nd:YAG lasers. EX1004, [0001]-[0002] (teaching use of “diode laser” and “Nd:YAG” in medical applications; “The present use of lasers in medical procedures and surgical applications is virtually unlimited.”), [0003] (“Light energy focused on tissue during medical procedures results in local hyperthermia, coagulation, or vaporization depending on the power density of the radiation energy.”), [0004] (“[D]epending on the desired effect of a medical laser, a small or large spot size is chosen.”), [0010] (“[T]hese systems incorporate solid state laser systems...”), [0012] (“Another object of the present invention is to provide a medical diode laser system that allows for simultaneous coagulation, and cutting or ablation of tissue.”). EX1005, 4:51-56 (teaching use of “a laser diode [and] a Nd:YAG laser, or the like” as optical inputs into a multicore output fiber). Each of the patents also explains that the output beam will have different properties depending on the core through which it travels; the light will only travel through the cores because it will be reflected from the lower

refractive index cladding into the higher refractive index cores in a phenomenon known as “total internal reflection.” EX1004, [0021] (“In operation, the fiber cores are both surrounded by lower refractive index material, which creates total internal reflection inside the individual fiber cores.”). EX1005, 2:67-3:2 (“...the index of refraction of the cladding is lower than the indices of refraction of the cores to confine optical beams within the cores.”), 3:22-27 (“[T]he indices of refraction of the cladding and the indices of refraction of the cores are chosen such that optical radiation propagating within the cores is substantially restricted to propagating along optical paths that pass through the cores and the ends of the cores.”), 3:39-41 (“The index of refraction of the cladding is lower than the indices of refraction of the cores to confine one or more optical beams to the cores,...”), 3:50-53 (“[T]he index of refraction of the cladding is lower than the indices of refraction of the cores to substantially confine optical beams to within the cores,...”), claims 1-12 (“[T]he index of refraction of said cladding being lower than the indices of refraction of said cores to confine optical beams to said cores,”).

74. **Second**, Davis teaches that a **first** and **second** incoming beam can be **coupled** to the output fiber by a **first** and **second** input fiber. In between the input fibers and the output fiber, optical elements such as **lenses** can be placed to selectively guide the input beams into different cores of the output fiber. EX1005, 4:12-13 (“an optical signal is refractively coupled into one of the cores of a multiple

core optical fiber”), 5:32-35 (“Optical beams 40 and 42 emanate from one or more optical sources 44 and enter, via refraction, respective cores 46 and 48 of an optical fiber 50, in which the cores 46 and 48 are surrounded by a cladding 52.”), 6:21-23 (“In this embodiment,... the inputs and outputs preferably involve the use of single-core fibers 43a-d”). Combining Davis’ coupling method with Neuberger’s concentric core output fiber amounts to nothing more than use of a known technique (using single core optical fibers and lenses to couple incoming light to the different cores of an output fiber) to a known device ready for improvement (a concentric core output fiber with no teaching of how to couple incoming light to the cores) to yield predictable results (using single core optical fibers and lenses to couple incoming light to the different cores of a *concentric* output fiber.)

75. **Finally**, Neuberger and Davis both teach the use of Nd:YAG or diode lasers. *See* EX1004, [0001] (“The present invention relates to diode laser systems that transmit at least two wavelengths or power densities of light energy...”), [0002] (“Solid state lasers, such as the Nd:YAG, have primarily been employed to achieve the desired optical power and wavelength for medical procedures...”), [0013] (“[A]nother object of the present invention is to provide a multiple core fiber which allows simultaneous transmission of both high power density radiation...that may be used for tissue cutting or ablating, and lower power density radiation that may be used for tissue coagulation and/or biostimulation.”); EX1005, 4:51-66 (“[A]n optical

beam 40 from an optical source 44 (such as a laser diode, ... a Nd:YAG laser, or the like) enters, via refraction, a core 46 of an optical fiber 50 ...”). A POSITA would therefore have found it obvious to try **coupling** the **first** and **second** laser beams from Davis’ **first** and **second input fibers** (e.g., Nd:YAG and diode laser, respectively) to Neuberger’s concentric multicore fiber to generate output beams with **different beam profile characteristics** (e.g., the beam from the inner core with a small spot size and higher intensity for cutting and the beam from the outer ring core for a larger spot size and lower intensity for coagulation).

3. Claims 2 and 3

- a) [2] The system of claim 1, wherein the system is configured to **couple** the **first input laser beam only** into the **inner fiber core** of the multi-clad fiber.
- b) [3] The system of claim 1, wherein the system is configured to **couple** the **second input laser beam only** into the at least one **outer ring core** of the multi-clad fiber.

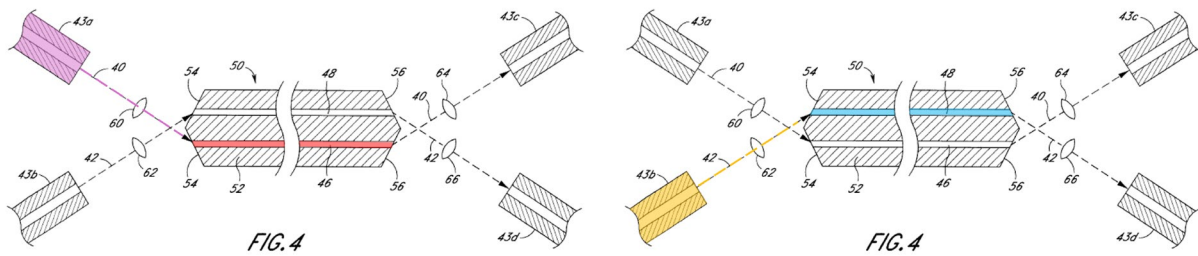
76. Neuberger and Davis render obvious the system of claim 1. *See* Section VIII.A.1 [Claim 1]. Neuberger and Davis further render obvious the added limitations of [2] and [3]. In Davis’ system, each of the input laser beams 40 and 42 is **only** coupled to a single core, either 46 or 48, or the multi-core fiber and none of the input laser beams is coupled into either of the **claddings**. EX1005, 1:12-22 (“Two cores 12 and 14 within a fiber 16 support respective propagating beams 18 and 20... The cores 12 and 14 are surrounded by a **cladding**... The index of

refraction of the **cladding 17** is lower than the indices of refraction of the cores **12** and **14** *so that optical energy is guided within the cores through total internal reflection.*”).

77. Davis makes a point that the cores must have a higher refractive index than the **cladding** so as “*to confine optical beams within the cores.*” EX1005, 2:67-3:2 (“[T]he index of refraction of the cladding is lower than the indices of refraction of the cores to confine optical beams within the cores.”); *see also id.*, 3:39-41 (“The index of refraction of the cladding is lower than the indices of refraction of the cores to confine one or more optical beams to the cores...”), 3:50-53 (“[T]he index of refraction of the cladding is lower than the indices of refraction of the cores to substantially confine optical beams to within the cores...”), claims 1-12 (“[T]he index of refraction of said cladding being lower than the indices of refraction of said cores to confine optical beams to said cores...”), 3:22-27 (“[T]he indices of refraction of the **cladding** and the indices of refraction of the cores are chosen such that optical radiation propagating within the cores is substantially restricted to propagating along optical paths that pass through the cores and the ends of the cores.”). With this guidance, Davis is simply exploiting the phenomenon of total internal reflection in which light is totally reflected back from a lower refractive index medium into a higher refractive index medium. EX1004, [0006]. As suggested by the name, “*total* internal reflection” refers to the phenomenon in which

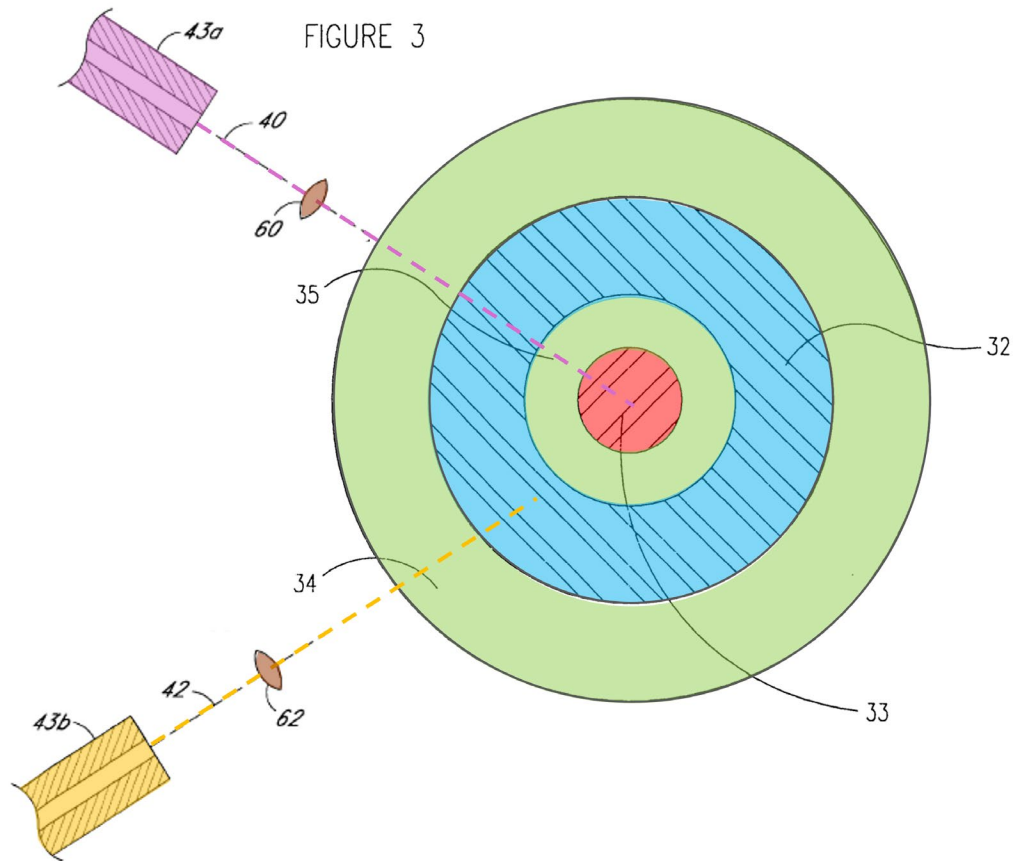
light propagating in a higher refractive material (such as the cores) and incident upon the core-cladding interface at an angle greater than the critical angle is reflected back into the core rather than transmitted into the lower refractive index cladding.

78. In Figure 4 of Davis, which I have annotated below, the first input laser beam 40 is *only coupled* to the core 46 and is not at all coupled to either core 48 or cladding 52. Likewise, the second input laser beam 42 is *only coupled* into the core 48 and is not coupled into either core 46 or cladding 52. EX1005, 2:67-3:2 (“[T]he index of refraction of the cladding is lower than the indices of refraction of the cores to confine optical beams within the cores.”), 3:39-41 (“The index of refraction of the cladding is lower than the indices of refraction of the cores to confine one or more optical beams to the cores...”), 3:50-53 (“[T]he index of refraction of the cladding is lower than the indices of refraction of the cores to substantially confine optical beams to within the cores...”), (“[T]he index of refraction of said cladding being lower than the indices of refraction of said cores to confine optical beams to said cores...”), 3:22-27 (“[T]he indices of refraction of the cladding and the indices of refraction of the cores are chosen such that optical radiation propagating within the cores is substantially restricted to propagating along optical paths that pass through the cores and the ends of the cores.”).



EX1005, FIG. 4.

79. It would have been obvious to a POSITA to combine these teachings and **coupled** the **first input laser beam 40** from **first optical fiber 43a only** into the **inner core 33** of Neuberger's concentric multicore output fiber. Similarly, it would have been obvious to a POSITA to couple a **second input laser beam 42** from **second optical fiber 43b only** into the **outer ring core 32** of Neuberger's concentric multicore output fiber. I have illustrated how this combination would look below.



See EX1005, FIG. 4 and EX1004, FIG. 3.

80. This combination would have been obvious to a POSITA because Neuberger explains that the output beam will have different beam profile characteristics depending on the core into which it is coupled. EX1004, [0001] (“The present invention relates to diode laser systems that transmit at least two wavelengths or power densities of light energy through a single step index fiber system having at least two core sections”), [0004] “[D]epending on the desired

effect of a medical laser, a small or large spot size is chosen.”), [0014] (“Radiation of a suitable wavelength for tissue cutting or ablating is coupled into an **inner fiber core** to produce an output beam with sufficient power density for ablation. Radiation of a suitable wavelength for tissue coagulation is introduced into an **outer fiber core** to produce another output beam with a lower power density appropriate for coagulation.”), [0018] (“Small spot 19 has sufficient power density to cut or ablate tissue 11.”), [0019] (“Large spot 20 has a lower power density suitable for tissue 11 coagulation.”), [0021] (“**Inner fiber core 33** transmits **high power density radiation** and is surrounded by **inner cladding 35**. **Inner cladding 35** is surrounded by **outer fiber 32**, which transmits the second wavelength radiation.”); *see also* Section VIII.A.1.a) [Claim 1Pre]. A POSITA would understand that it is important to prevent crosstalk between the two cores so that cutting applications do not inadvertently result in coagulation, and vice versa.

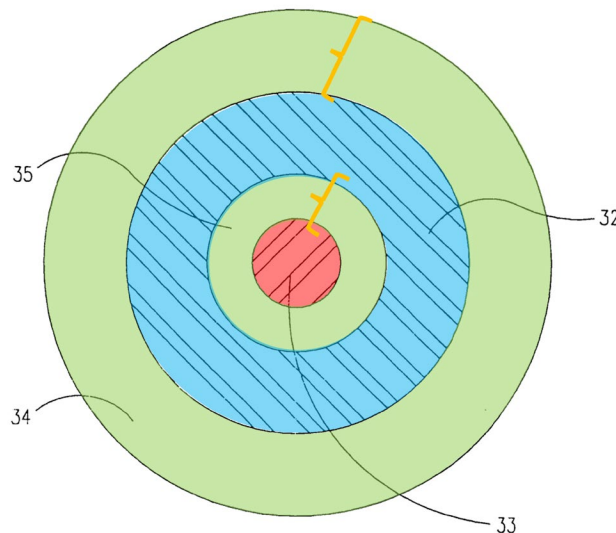
4. Claim 4

- a) [4A] The system of claim 1, wherein the multi-clad fiber comprises **one or more claddings** respectively **around** the **inner fiber core** and the at least one **outer ring core**, and
- b) [4B] wherein the system is configured such that no laser beam is **coupled** into the **one or more claddings**.

81. Neuberger and Davis render obvious the system of claim 1. *See* Section VIII.A.1 [Claim 1]. Neuberger and Davis further render obvious the added

limitations of [4A] and [4B]. In Figure 3, Neuberger shows that the multicore output fiber features cladding 35 and cladding 34 around both the inner core 33 and the outer ring core 32.

FIGURE 3



EX1004, FIG. 3; *see also* EX1004, [0014] (“[M]aterial functioning as an intermediary cladding separates the outer and inner fiber cores.”), [0021], claims 9 and 12. Davis similarly explains that “the cores 46 and 48 are separated from one another and are surrounded by a cladding 52.” EX1005, 4:55-56

82. Neuberger explains that it’s important for ***all input radiation [to be] confined within the cores*** via total internal reflection. EX1004, [0006] (“***All*** incident radiation is advantageously reflected back into the optical fiber core.”). EX1004, [0021] (“[T]he fiber cores are both surrounded by lower refractive index material, which creates ***total internal reflection*** inside the individual fiber cores.

This *total internal reflection* has the added advantage of diminished cross-talk between cores.”). A POSITA would understand that this could be achieved by making the refractive index of the **cladding** lower than the refractive index of the cores. Light would then reflect from the **cladding** back into the cores.

83. Davis likewise explains that laser beams are only **coupled** into the cores and not into **cladding**. *First*, Davis refers to prior art that teaches “the index of refraction of the **cladding** 17 is lower than the indices of refraction of the cores 12 and 14 so that optical energy is guided within the cores through *total internal reflection*.” EX1005, 1:19-22. As I explained above, in “total internal reflection” light is totally reflected from the lower refractive index claddings into the higher refractive index cores. This means it should not enter the claddings. *Second*, Davis emphasizes that the output fiber is designed so as “to *confine* the optical beams *within the cores*.” EX1005, 2:65-3:2, 3:24-27, 3:39-41, 3:53-54, claims 1-12. (“[O]ptical radiation propagating within the cores is substantially restricted to propagating along optical paths that pass through the cores and the ends of the cores.”). Both Neuberger and Davis therefore teach that the input laser beams are not coupled into the claddings of the multicore output fiber.

5. Claim 5

- a) [5Pre] The system of claim 1, wherein the multi-clad fiber is configured to have *at least one of*:
- b) [5A] the **inner fiber core** with a diameter of no greater than 200 μm ,
- c) [5B] the at least one **outer ring core** with a diameter of no greater than 600 μm , or
- d) [5C] an **inner cladding** with a thickness of no greater than 10 μm , the **inner cladding** being **between** the **inner fiber core** and the at least one **outer ring core**.

84. Neuberger and Davis render obvious [5Pre] for the reasons I provided above in Section VIII.A.1.a) for [1Pre]. Neuberger and Davis also render obvious claim 5. Since claim 5 uses “or,” only one of [5A], [5B], or [5C] must be met. As I explain below, Neuberger in combination with Davis renders obvious at least [5A].

85. Neuberger does not teach the diameter of its **inner fiber core** but Davis states that the cores can have a diameter far below 200 μm . EX1005, 4:63-64 (“[T]he cores 46 and 48 may be, for example, **8 microns** in diameter”). A POSITA would have found it obvious to use the 8 micron core sizes suggested by Davis in the **inner fiber core** of Neuberger’s multicore fiber. This combination would amount to nothing more than applying the known technique of an 8 micron core diameter to Neuberger’s multicore fiber, which is a known device ready for improvement, to yield the predictable result of Neuberger’s multicore fiber with an 8 micron **inner fiber core diameter**.

86. This combination would be obvious to try since both the output fibers in Neuberger and Davis can transmit Nd:YAG or diode lasers, (*see* EX1004, [0001], [0002], [0013]; EX1005, 4:51-66).

6. Claim 6

- a) [6] The system of claim 1, wherein the multi-clad fiber comprises the **inner fiber core** with a **refractive index n_1** , a **first cladding** with a **refractive index n_2** , and an **outer ring core** with a **refractive index n_3** , and the **first cladding surrounds** the **inner fiber core** and is **between** the **inner fiber core** and the **outer ring core**, and wherein **$n_1 = n_3$** and **$n_1 > n_2$** .

87. Neuberger and Davis render obvious the system of claim 1. *See* Section VIII.A.1 [Claim 1]. Claim [6] requires two additional limitations, which are that the **inner** and **outer** cores must have the **same refractive index ($n_1 = n_3$)** and that the refractive index of the **inner core** must be **higher than** the refractive index of the **inner cladding ($n_1 > n_2$)**. Neuberger in combination with Davis renders obvious [6].

88. **First**, Neuberger teaches that the refractive indices of the inner core and the outer core, n_1 and n_3 respectively, are both **higher than** the refractive indices of the inner cladding and outer cladding, n_2 and n_4 , respectively. This meets the requirement that **$n_1 > n_2$** .¹ *See* EX1004, [0014] (“[T]he **inner core** has a **larger**

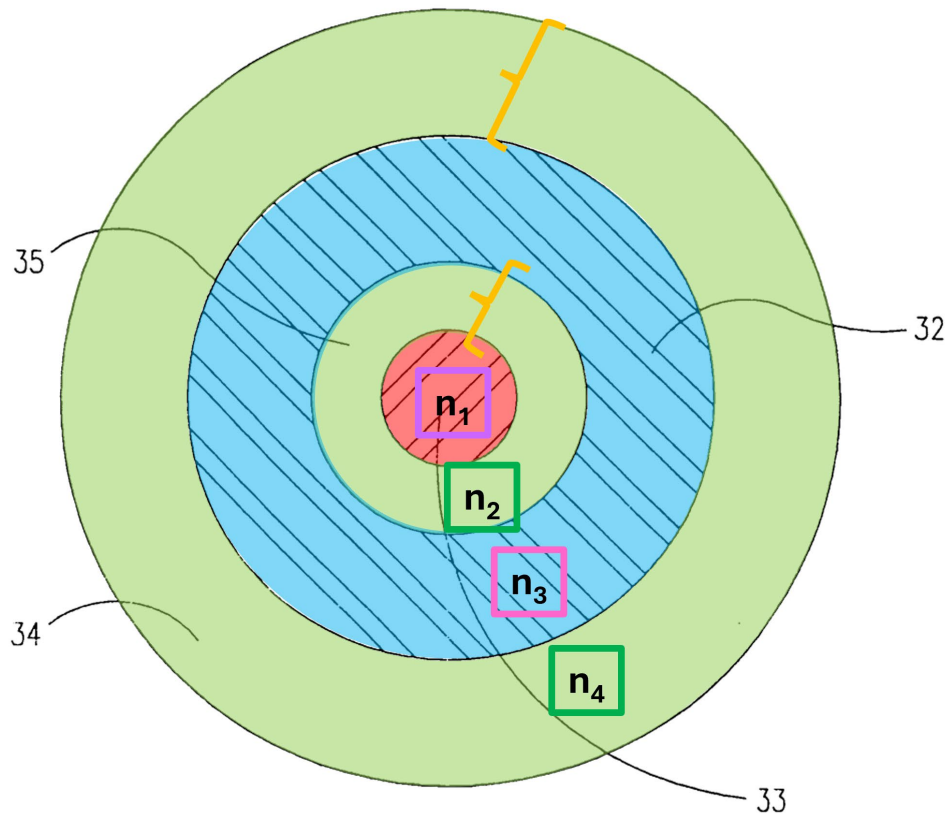
¹Davis explains that “the index of refraction of the cladding 17 is lower than the indices of refraction of the cores 12 and 14 so that optical energy is guided within

refractive index than the inner cladding which in turn has a lower refractive index than the outer core, which is surrounded by an outer cladding also having a refractive index lower than the outer fiber core.”); see also EX1004, [0021] (“Inner fiber core 33 transmits high power density radiation and is surrounded by inner cladding 35. Inner cladding 35 is surrounded by outer fiber core 32, which transmits the second wavelength radiation. Outer cladding 34 forms the fourth layer and surrounds outer fiber core 32. *The refractive index of inner fiber core 33 is larger than the refractive index of inner cladding 35* which also has a smaller refractive index than outer fiber core 32. Outer cladding, which forms the fourth concentric layer has a refractive index smaller than outer fiber core 32.”).

89. **Second**, even though Neuberger does not offer the values of the refractive indices of the inner core (n_1) and outer core (n_3), a POSITA would have found it obvious to use cores with the same refractive indices such that $n_1=n_3$.

the cores through total internal reflection.” EX1005, 1:19-23. Davis also explains that cladding has a lower refractive index than the cores. EX1005, 2:67-3:1, 3:39-40, 3:50-51, claims 1-12.

FIGURE 3



EX1004, FIG. 3. Neuberger states that for the non-concentric core embodiments shown in Figures 7 and 8 that “the fiber cores may have **similar refractive indices**.” EX1004, [0026]; *But cf.* EX1004, [0023] (explicitly noting “FIG. 4-6 all have an inner core with a refractive index greater than the outer core which in turn has a greater refractive index than the cladding layer.”). A POSITA would have found it obvious to make the concentric cores have similar refractive indices, too. To the extent “similar refractive indices” does not explicitly teach $n_1=n_3$, it would have been obvious since the requirement that $n_1=n_3$ is not critical.

90. If the two cores are made of the same material, they will have the same refractive index. A POSITA would have found it obvious to give the cores equal refractive indices by making them with the same material. The combination is therefore nothing more than applying a known technique (making the cores from the same material so they have the same refractive index) to a known device ready for improvement (Neuberger's concentric multicore output fiber that must eliminate cross-talk between the cores) to yield the predictable result of total internal reflection that confines the transmitted light to only the inner and outer cores. EX1004, [0014] ("[T]hese embodiments allow for transmission of high and low power density radiation that can be used for efficient cutting or ablation, bio-stimulation and coagulation of various tissues."), [0021] ("[T]he fiber cores are both surrounded by lower refractive index material, which creates total internal reflection inside the individual fiber cores. This total internal reflection has the added advantage of diminished cross-talk between cores."), [0026] ("In both FIG. 7 and 8, the fiber cores may have similar refractive indices, but the cladding must have a smaller refractive index. Embodiments shown in FIG. 7 and 8 may be particularly useful in applications where a site must be cut or ablated, but an area immediately to one side of the site will be harmed by any radiation exposure."). EX1005, 3:20-27 ("[T]he indices of refraction of the cores are chosen such that optical radiation propagating within the cores is substantially restricted to propagating along optical paths that

pass through the cores.”), claims 1-12 (“[T]he index of refraction of said cladding being lower than the indices of refraction of said cores to confine optical beams to said cores...”).

91. A POSITA would also have known it would be simpler to fabricate the inner and outer cores of the multicore fiber using the same materials than to make them using different materials. Using the same materials would result in more predictable fabrication conditions because the materials could be processed using the same techniques and processing conditions. A POSITA would know that the output fiber “can be made by standard optical fiber processing techniques.” EX1007, 1:59-61. Such techniques, such as chemical vapor deposition, were well-known for over 30 years before the priority date of the '054 Patent. For example, Goell explains that “[o]ne method for forming the multi-core fiber could consist in the successive application of a number of layers of material by the process known as chemical vapor deposition ... [in which t]he material contributing to the higher index region [*i.e.*, cores] would be germania-silica glass, for example, and the material contributing to the lower index of refraction [*i.e.*, claddings] would be borosilicate glass.” EX1007, 1:62-2:2. It would therefore have been obvious to a POSITA to manufacture the output fiber using such standard techniques and making the inner and outer cores from the same germania-silica glass material.

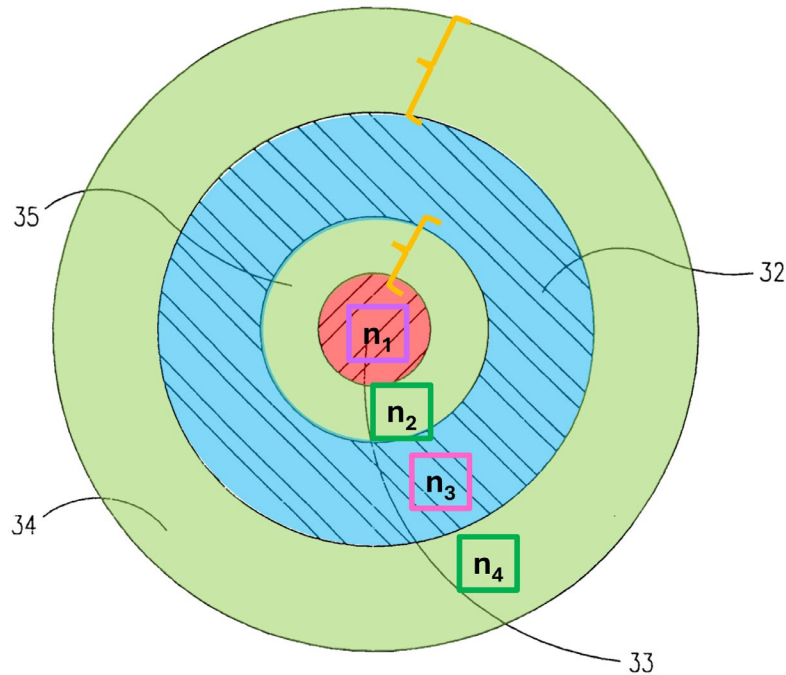
7. Claim 7

- a) [7] The system of claim 6, wherein the multi-clad fiber further comprises a second cladding surrounding the outer ring core, and wherein a refractive index n_4 of the second cladding is identical to the refractive index of the first cladding n_2 .

92. Neuberger and Davis render obvious the system of claim 6. *See* Section VIII.A.1 [Claim 1]. Claim 7 depends on claim 6 and adds the requirement that the multi-clad fiber (1) includes a second cladding surrounding the outer ring core and (2) the first and second claddings have the same refractive index ($n_2 = n_4$). Neuberger renders obvious the added limitations of [7].

93. Figure 3 of Neuberger, which I have colored below, shows that there is a second cladding surrounding the outer ring core. *See* EX1004, [0021] (“Outer cladding 34 forms the fourth layer and surrounds the outer fiber core 32.”).

FIGURE 3

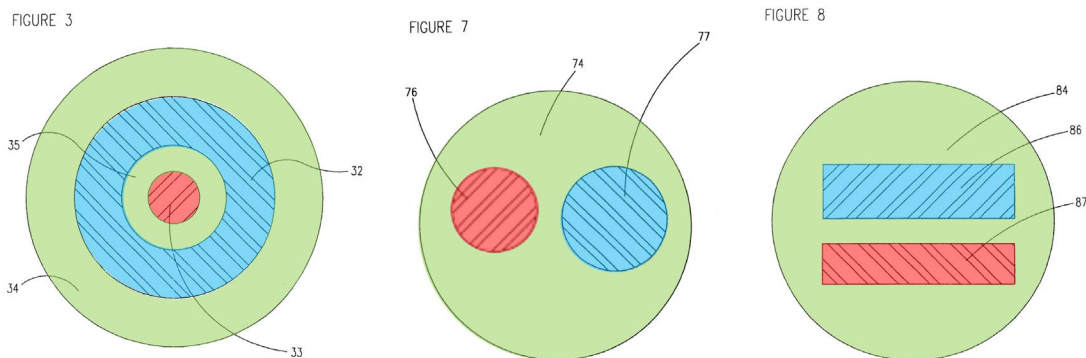


EX1004, FIG. 3.

94. Although Neuberger does not provide any values for the refractive indices of the inner and outer claddings, n_2 and n_4 , respectively, a POSITA would have been obvious to use claddings with the same refractive indices such that $n_2=n_4$. Neuberger teaches that the inner and outer cladding refractive indices, n_2 and n_4 , must both be lower than the inner and outer core refractive indices, n_1 and n_3 , respectively. See EX1004, [0014] (“[T]he inner core has a larger refractive index than the inner cladding which ... has a lower refractive index than the outer core, which is surrounded by an outer cladding also having a refractive index lower than the outer fiber core.”); see also EX1004, [0021] (“The refractive index of inner fiber

core 33 is larger than the refractive index of inner cladding 35 which ... has a smaller refractive index than outer fiber core 32. Outer cladding, which forms the fourth concentric layer has a refractive index smaller than outer fiber core 32.”).

95. It was well-known in the art for the claddings that surround the cores to have the same refractive index. Even Neuberger explains that “[i]n both FIG. 7 and 8, the fiber cores may have similar refractive indices, but the **cladding** must have a smaller refractive index.” EX1004, [0026]. In Neuberger’s Figures 7 and 8, both cores are surrounded by the **same cladding** material. A POSITA would have understood that each of the cores in a concentric core optical fiber could then also have the same refractive index such that $n_2=n_4$.



EX1004, FIGS. 3, 7, 8.

96. Neuberger explains that “[i]n operation, the fiber cores are both surrounded by **lower refractive index material** [note: **singular, not plural**], which creates total internal reflection inside the individual fiber cores. This total internal

reflection has the added advantage of diminished cross-talk between cores.” *See* EX1004, [0021].

97. As I explained in Section VIII.A.6 [Claim 6] above, a POSITA would also have known it would be simpler to fabricate the inner and outer cores of the multicore fiber using the same materials than to make them using different materials. Using the same materials would result in more predictable fabrication conditions because the materials could be processed using the same techniques and processing conditions. The combination is therefore nothing more than application of a known technique (making the claddings from the same lower refractive index material, which will result in them having the same lower refractive index) to a known device ready for improvement (Neuberger’s multicladd optical fiber) to yield predictable results (the system of Neuberger and Davis in which light is totally reflected from the claddings back into the inner and outer cores). EX1004, [0026] (“In both FIG. 7 and 8, the fiber cores may have similar refractive indices, but the cladding must have a smaller refractive index. Embodiments shown in FIG. 7 and 8 may be particularly useful in applications where a site must be cut or ablated, but an area immediately to one side of the site will be harmed by any radiation exposure.”). EX1005, 2:67-3:2 (“[T]he index of refraction of the cladding is lower than the indices of refraction of the cores to confine optical beams within the cores.”), 3:20-27 (“[T]he indices of refraction of the cladding and the indices of refraction of the

cores are chosen such that optical radiation propagating within the cores is substantially restricted to propagating along the optical paths that pass through the cores...”), 3:39-41 (“The index of refraction of the cladding is lower than the indices of refraction of the cores to confine one or more optical beams to the cores,”), 3:49-53, 4:66-5:3 (“An optical element such as a lens 60 is preferably used to focus the optical beam 40 onto the core 46. The fiber 50 and the optical element 60 may be aligned using standard alignment apparatuses, for example, micropositioners (not shown).”, claims 1-12 (“[T]he index of refraction of said cladding being lower than the indices of refraction of said cores to confine optical beams to said cores...”). EX1007, 1:40-42 (“An intermittent cladding layer of lower index material prevents an intermixing between the secret information and the security signal.”), 2:25-40 (“An inner cladding layer of an index of refraction n_3 completely encloses the signal core for confining light energy within the signal core by the method of complete internal refraction...”), 2:49-52 (“Light from one source can ... travel through the signal core, and light from an independent source could travel through the alarm core with no interference or intermixing between the two light signals.”), claims 1, 2, and 4 (“[A]n inner cladding layer ... surrounding said inner core having a second index of refraction lower than the first index of refraction for confining light energy within said inner core;... at least one outer cladding layer...surrounding said outer core and

having an index of refraction lower than said outer core for confining light energy within said outer core.”).

98. A POSITA would have known they could make the inner and outer claddings from the same material using “standard optical fiber techniques” so that $n_2=n_4$. EX1007, 1:59-61. As I explained above in Section VIII.A.6 [Claim 6], a POSITA would know that such techniques have existed since even 1976. Goell teaches “[o]ne method for forming the multi-core fiber could consist in the successive application of a number of layers of material by the process known as chemical vapor deposition ... [in which t]he material contributing to the higher index region [*i.e.*, cores] would be germania-silica glass, for example, and the material contributing to the lower index of refraction [*i.e.*, claddings] would be borosilicate glass.” EX1007, 1:62-2:2. It would therefore have been obvious to a POSITA to manufacture the output fiber using such standard techniques and making the inner and outer claddings from the same borosilicate glass material.

8. Claim 8

- a) [8] The system of 1, wherein the multi-clad fiber comprises **two or more outer ring cores**, and the system is configured to couple two or more corresponding input laser beams into the **two or more outer ring cores**.

99. Neuberger in combination with Davis renders obvious the system of claim 1. *See* Section VIII.A.1 [Claim 1]. Neuberger in combination with Davis further renders obvious [8].

100. Neuberger indicates that a multicore optical fiber could use **multiple outer ring cores** to transmit **additional** wavelengths of light. EX1004, [0017] (“The present invention provides a device that allows for concurrent transmission of **at least** two wavelengths or at least two power densities which can for example simultaneously cut or vaporize and coagulate tissue. ... Furthermore, the present invention is not limited to transmission of only two wavelengths or power densities. **Additional concentric layers** can be added to the fiber to transmit **additional** wavelengths.”).

101. Neuberger therefore teaches a multicore output fiber having two or more outer ring cores—the **outer ring core 32** in Figure 3 and the “[a]dditional concentric layers” in EX1004, [0017]. As Neuberger explains, the two or more **outer ring cores** would couple to two or more input beams, and therefore “transmit additional wavelengths.” EX1004, [0017]. Neuberger explains that “radiation of

suitable wavelengths” is coupled into the various cores of its multicore fiber, which a POSITA would understand to teach that two or more input beams could be coupled into the **two or more outer ring cores**. EX1004, claim 1 (“a single optical delivery fiber (18) wherein said delivery fiber has **at least two core sections** (15, 16) of different cross-sectional area **to transmit radiation from at least two laser sources**, ... to achieve separately a beam of light output (12) to cut tissue, and... separately a laser light output (13) to coagulate or biostimulate tissue being cut.”); *see also id.*, [0013], [0014] (explaining that “[r]adiation of a suitable wavelength” is coupled into an “**inner fiber core**” and “**outer fiber core**”).

102. It was well-known in the art to couple multiple different laser beams into multiple different cores of a multicore output fiber. Davis teaches that “other embodiments work with fibers having **three or more cores**.” As I explained in Section VIII.A.1.c) [Claim 1B] , even though Davis’ cores are not concentric, Neuberger teaches that concentric and non-concentric cores are interchangeable. *See* EX1004, claims 9 and 12 and FIGS. 3, 7, and 8. EX1005, 6:14-15; Figures 11, 13; 8:26-30 (noting that “in principle the fiber may include an arbitrary number of cores.”). EX1005, 9:12-13 (“In general, the number of cores in a fiber determines the number of potential inputs and outputs.”). In addition, Davis explains that “an optical fiber is provided that comprises ... a plurality of cores within the cladding, in which the indices of refraction of the cladding and the indices of refraction of the

cores are chosen such that optical radiation propagating within the cores is substantially restricted to propagating along optical paths that pass through cores and the ends of the cores.” EX1005, 3:20-26.

103. Since Neuberger teaches that the output fiber can contain additional concentric rings to “transmit additional wavelengths” from “at least” two laser sources via “[a]dditional concentric layers” and Davis teaches that additional cores are used to propagate optical radiation, the combination of Neuberger and Davis renders obvious the added limitations of [8].

9. Claim 10

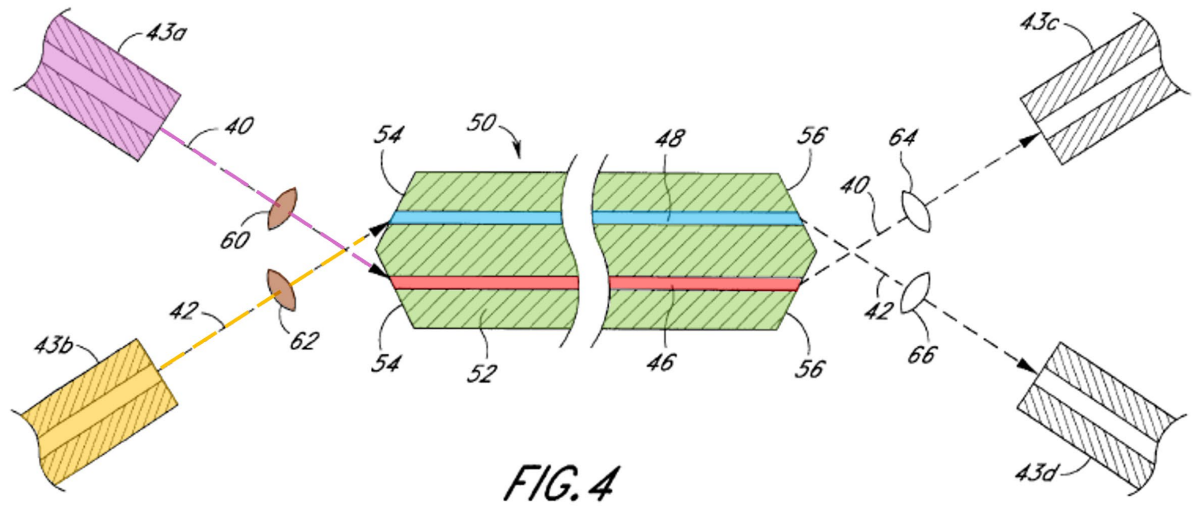
- a) [10Pre] The system of claim 1, further comprising a **switchable device coupled between the first and second optical fibers and the multi-clad fiber,**
- b) [10A] wherein the **switchable device** is configured to **electively couple the first input laser beam** at least into the **inner fiber core** of the multi-clad fiber and the **second input laser beam** at least into the at least one **outer ring core** of the multi-clad fiber.

104. Neuberger and Davis render obvious the system of claim 1. *See* Section VIII.A.1 [Claim 1]. Neuberger in combination with Davis renders obvious [10].

105. The '054 Patent states that “[i]n a preferred embodiment ..., the **switchable device** is formed by **mobile optics**. ... The **mobile optics** can, for example, be prisms, plane-parallel (glass) plates, **convex and concave lenses**,

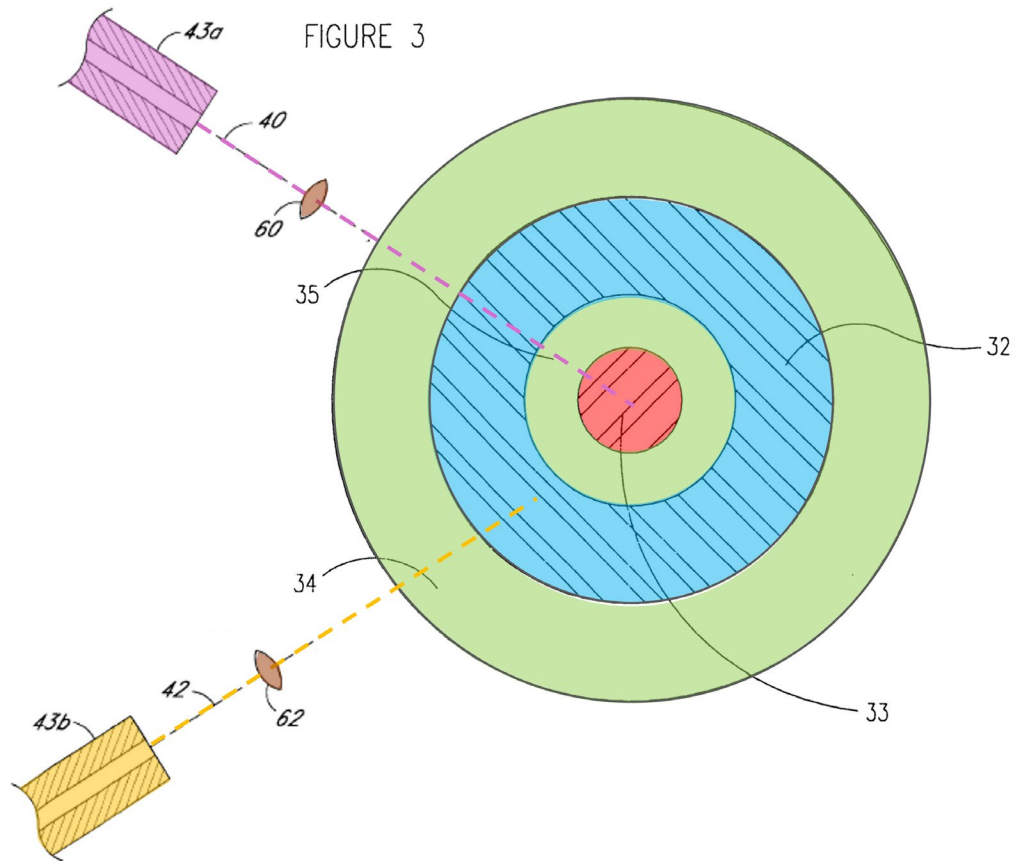
mirrors, diffractive optical elements, etc., *individually* or in combinations.”
EX1001, 4:40-43.

106. Davis teaches this method, explaining that “optical elements such as lenses 60 and 62 may be used to focus the optical beams 40 and 42 onto the individual cores 46 and 48.” EX1005, 5:43-45; *see also* EX1005, 5:58-65 (describing that “lenses 60 and 62 can be any type of focusing optical elements,” can “refer to either one kind of lens or a combination of lenses,” and can be “close enough” to fiber 50 to focus the beams onto their respective cores). Davis’ lenses are situated on moveable stages and can guide the input beams (40 and 42) into the different cores (46 and 48). EX1005, 5:40-45 (“...the various optical components may be fixed, for example, within respective mechanical mounts resting upon respective translation stages to control the alignment of the optical beams 40 and 42, which propagate along optical paths within the cores 46 and 48.”). Moving the translation stages that carry the lenses 60 and 62 allows one to **electively couple** input beams 40 and 42 into either of cores 46 or 48 of the output fiber, as I have illustrated in Figure 4 of Davis.



EX1005, FIG. 4.

107. And as I explained in Sections VIII.A.1.c) [Claim 1B] and VIII.A.3 [Claims 2 and 3], a POSITA would have seen that Davis' **first input laser beam 40** from **a first optical fiber 43a** could be **electively coupled** by **optical element 60** into the **inner core 33** of Neuberger's output fiber. Similarly, Davis' **second input laser beam 42** could be **electively coupled** to **optical element 62** into the **outer ring core 32** of Neuberger's output fiber. I have illustrated this combination below.



See EX1005, FIG. 4 and EX1004, FIG. 3.

10. Claim 11

- a) [11Pre] A method of generating a laser beam with different beam profile characteristics, the method comprising:**

108. Neuberger in combination with Davis renders obvious [11Pre].

Neuberger in combination with Davis teaches generating a laser beam with

different beam profile characteristics, such as for cutting and coagulating, as I explained in Section VIII.A.1.a) for [1Pre].

- b) [11A] guiding a **first input laser beam** by a **first optical fiber** to a fiber end of a multi-clad fiber, wherein the multi-clad fiber has an **inner fiber core** and at least one **outer ring core**;

109. Neuberger in combination with Davis renders obvious [11A] for the reasons I provided in Sections VIII.A.1.b) and VIII.A.1.c) for [1A]-[1B]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

- c) [11B] guiding a **second input laser beam** by a **second optical fiber** to the fiber end of the multi-clad fiber;

110. Neuberger in combination with Davis renders obvious [11B] for the reasons I provided in Section VIII.A.1.c) for [1C]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

- d) [11C] **coupling** the **first input laser beam** and the **second input laser beam** into the fiber end of the multi-clad fiber, comprising at least one of:

111. Neuberger in combination with Davis renders obvious [11C] for the reasons I provided in Section VIII.A.1.c) for [1B]-[1D]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

- e) [11D] **coupling** the **first input laser beam** at least into the **inner fiber core** of the multi-clad fiber, or

112. Neuberger in combination with Davis renders obvious [11D] for the reasons I provided in Section VIII.A.1.c) for [1B]-[1D]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

- f) [11E] **coupling** the **second input laser beam** at least into the at least one **outer ring core** of the multi-clad fiber; and

113. Neuberger in combination with Davis renders obvious [11E] for the reasons I provided in Section VIII.A.1.c) for [1B]-[1D]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

- g) [11F] generating an **output laser beam** by interaction of the **first input laser beam** and the **second input laser beam** with the multi-clad fiber, wherein a **beam profile characteristic of the output laser beam differs** depending upon the **coupling** of the **first input laser beam** and the **second input laser beam** into the fiber end of the multi-clad fiber.

114. Neuberger in combination with Davis renders obvious [11F] for at least the reasons I provided in Sections VIII.A.1.a), VIII.A.1.b), and VIII.A.1.c) for [1Pre]-[1D]. Additionally, as I discussed in Sections VIII.A.1.c) [Claims 1B-1D] and VIII.A.3 [Claims 2-3], by using Davis' **coupling method**, one may generate a **smaller circular beam profile with a higher intensity output** from the interaction of a **first input laser beam 40** with Neuberger's **inner core 33**. *See* Sections VIII.A.1.c) [Claims 1B-1D] and VIII.A.3 [Claims 2-3], EX1004, [0014],

[0021]. In addition, one may generate a larger ring-shaped beam profile with a lower intensity output from the interaction of a second input laser beam 42 with Neuberger's outer ring core 32. See Sections VIII.A.1.c) [Claims 1B-1D] and VIII.A.3 [Claims 2-3], EX1004, [0014], [0021]. See also Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

11. Claim 12

- a) [12Pre] The method of claim 11, wherein coupling the first input laser beam at least into the inner fiber core of the multi-clad fiber comprises:

115. Neuberger in combination with Davis renders obvious [12Pre] for the reasons I provided in Section VIII.A.1.c) for [1D]. See also Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

- b) [12A] coupling the first input laser beam only into the inner fiber core of the multi-clad fiber.

116. Neuberger in combination with Davis renders obvious [12A] for the reasons I provided in Section VIII.A.3.a) for [2]. See also Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

12. Claim 13

- a) [13Pre] The method of claim 11, wherein **coupling** the **second input laser beam** at least into the at least one **outer ring core** of the multi-clad fiber comprises:

117. Neuberger in combination with Davis renders obvious [13Pre] for the reasons I provided in VIII.A.1.c) for [1D]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

- b) [13A] **coupling** the **second input laser beam** only into the at least one **outer ring core** of the multi-clad fiber.

118. Neuberger in combination with Davis renders obvious [13A] for the reasons I provided in Section VIII.A.3.b) for [3]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

13. Claim 14

- a) [14Pre] The method of claim 11, wherein the multi-clad fiber comprises **one or more claddings** respectively **around** the **inner fiber core** and the at least one **outer ring core**, and

119. Neuberger in combination with Davis renders obvious [14Pre] for the reasons I provided in Section VIII.A.4.a) for [4A]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

- b) [14A] wherein **coupling** the **first input laser beam** and the **second input laser beam** into the fiber end of the multi-clad fiber comprises:

120. Neuberger in combination with Davis renders obvious [14A] for the reasons I provided in Section VIII.A.1.c) for [1B]-[1C] and Section VIII.A.3 for [2] and [3]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

- c) [14B] **coupling** no laser beam into the one or more **claddings**.

121. Neuberger in combination with Davis renders obvious [14B] for the reasons I provided in Section VIII.A.4.b) for [4B]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

14. Claim 15

- a) [15Pre] The method of claim 11, wherein the multi-clad fiber comprises an inner cladding between the inner fiber core and the at least one outer ring core, and wherein the multi-clad fiber is configured to have at least one of:
- b) [15A] the inner fiber core with a diameter of no greater than 200 μm ,
- c) [15B] the at least one outer ring core with a diameter of no greater than 600 μm , or
- d) [15C] the inner cladding with a thickness of no greater than 10 μm .

122. Neuberger in combination with Davis renders obvious [15] for the reasons I provided in Section VIII.A.5 for [5]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

15. Claim 16

- a) [16] The method of claim 11, wherein the multi-clad fiber comprises the inner fiber core with a refractive index n_1 , a first cladding with a refractive index n_2 , and an outer ring core with refractive index n_3 , and the first cladding surrounds the inner fiber core and is between the inner fiber core and the outer ring core, and wherein $n_1 = n_3$ and $n_1 > n_2$.

123. Neuberger in combination with Davis renders obvious [16] for the reasons I provided in Section VIII.A.6 for [6]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

16. Claim 17

- a) [17] The method of claim 16, wherein the multi-clad fiber further comprises a **second cladding** **surrounding** the **outer ring core**, and wherein a **refractive index n_4** of the **second cladding** is **identical** to the **refractive index** of the **first cladding n_2** .

124. Neuberger in combination with Davis renders obvious [17] for the reasons I provided Section VIII.A.7 for [7]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

17. Claim 18

- a) [18] The method of claim 11, wherein the multi-clad fiber comprises **two or more outer ring cores**, and the method comprises: coupling two or more corresponding input laser beams into the **two or more outer ring cores**.

125. Neuberger in combination with Davis renders obvious [18] for the reasons I provided in Section VIII.A.8 for [8]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

18. Claim 20

- a) [20Pre] The method of claim 11, wherein **coupling** the **first input laser beam** and the **second input laser beam** into the fiber end of the multi-clad fiber comprises: **electively coupling**, by a **switchable device coupled** between the **first** and **second optical fibers** and the fiber end of the multi-clad fiber, one of the **first input laser beam** at least into the **inner fiber core** of the multi-clad fiber and the **second input laser beam** at least into the at least one **outer ring core** of the multi-clad fiber.

126. Neuberger in combination with Davis renders obvious [20] for the reasons I provided in Section VIII.A.1.c) for [1B]-[1D] Section VIII.A.9.a) for [10Pre] and Section VIII.A.9.b) for [10A]. *See also* Section VIII.A.2 [Reasons To Combine Neuberger With Davis].

B. Ground II: Neuberger In Combination With Davis And Kalle Renders Obvious Claims 5 And 15

1. Claim 5

- a) [5Pre] The system of claim 1, wherein the multi-clad fiber is configured to have at least one of:

127. Neuberger and Davis render obvious [5Pre] for the reasons I provided in Section VIII.A.1.a) for [1Pre]. Neuberger in combination with Davis and Kalle renders obvious the remaining limitations of claim 5 for three independent reasons.

b) [5A] the inner fiber core with a diameter of no greater than 200 μm ,

128. Neuberger does not teach the diameter of its inner fiber core. However, as I explained above in Section VIII.A.5.b) [Ground 1, Claim 5A], a POSITA would have found it obvious to use the 8 micron core diameters taught by Davis for the diameter of Neuberger's inner fiber core. *See also* EX1005, 4:63-64 (“the cores 46 and 48 may be, for example, 8 microns in diameter”). I include this Ground to further show that it was well-known to have output optical fibers with inner fiber cores with diameters of less than 200 μm . Kalle discloses the same kind of output optical fiber as Neuberger, with “a first core section 11 ..., a barrier layer 12 ..., a second core section 13 ..., and a cladding 14 ...” EX1006, 15:21-23, claims 10, 24. Kalle additionally teaches that “the first core section (11) of the fiber (10) has a diameter (d_1) between 10 μm and 100 μm , or between 30 μm and 60 μm .” In one embodiment, as I have illustrated below, “[t]he diameter of the first core section 11 is about 40 μm .” EX1006, 21:18-19.

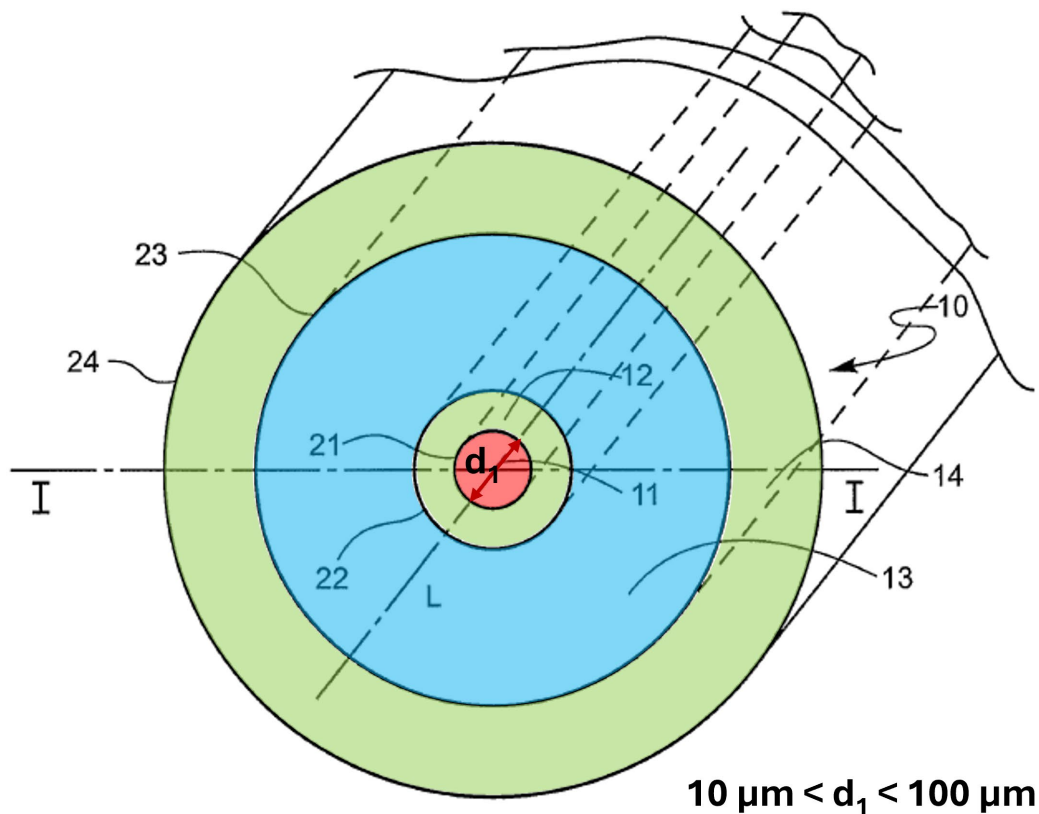


FIG. 1A

EX1006, FIG. 1A.

- c) [5B] the at least one **outer ring core** with a diameter of no greater than 600 μm , or

129. Kalle also teaches **outer ring cores** with diameters below 600 μm . In one instance, Kalle states that “the diameter of the **second core section 12** is about 200 μm .” EX1006, 21:19-20. Kalle’s Figure 3, as I have illustrated below, shows a range for the diameter of the **second core section**, which has the shape of a ring (see EX1006, FIG. 1). The smallest diameter is 180 μm and the largest diameter is

220 μm . These diameters fall well within the limitation for an “outer ring core with a diameter of no greater than 600 μm .”

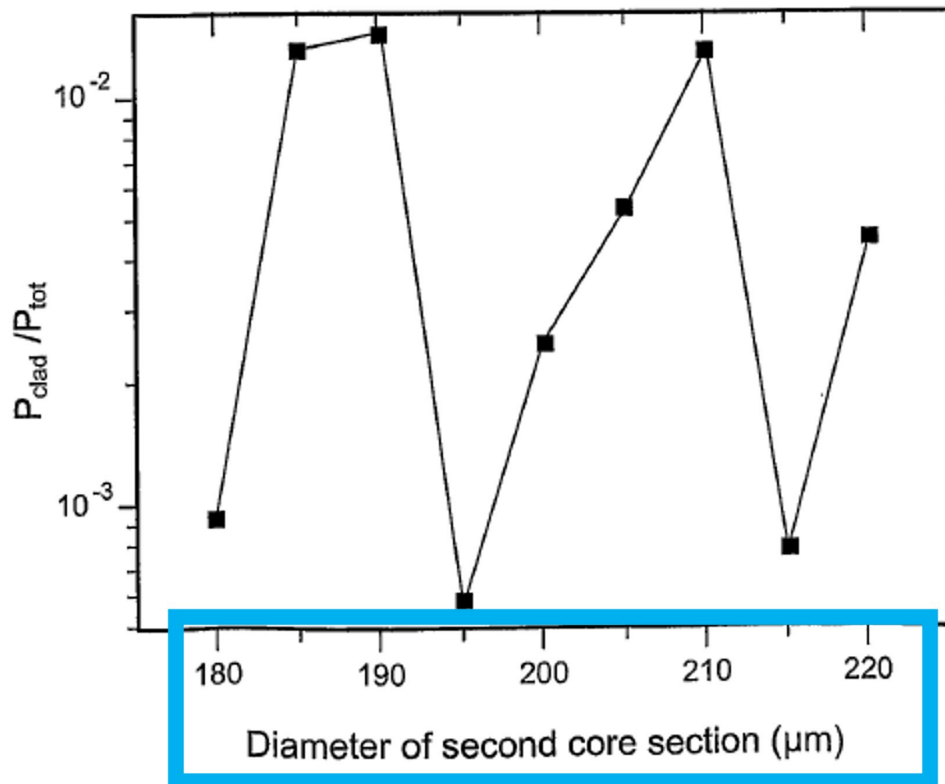


FIG. 3

EX1006, FIG. 3.

- d) [5C] an inner cladding with a thickness of no greater than 10 μm , the inner cladding being between the inner fiber core and the at least one outer ring core.

130. Kalle additionally teaches an inner cladding between the inner and outer cores with a thickness of less than 10 μm . Like Neuberger’s output fiber, Kalle’s fiber features “a barrier layer (12)” “between said first core section (11) and said second core section (13).” EX1006, claims 1, 15, 5:20-21. Kalle explains that

“[t]he thickness of the barrier layer is, for example, from 3 to 50 μm , preferably between 5 and 20 μm .” EX1006, 3:2-3, 15:3-5, claims 11, 25. In one case, “the thickness of the barrier layer 12 is about 10 μm ...” EX1006, 21:19. Kalle’s Figure 2, as I have annotated below, shows the barrier thickness is between 6 and 14 μm . Kalle’s barrier thickness therefore satisfies the limitation for a “thickness of no greater than 10 μm .”

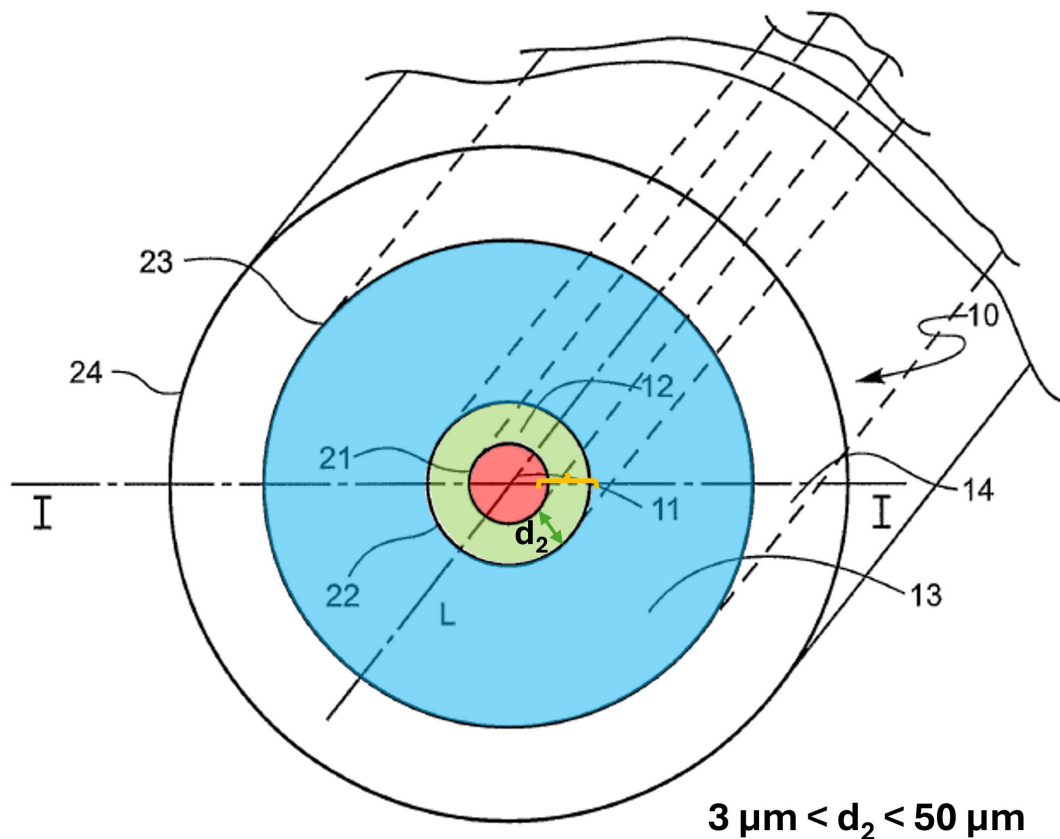


FIG. 1A

EX1006, FIG. 1A.

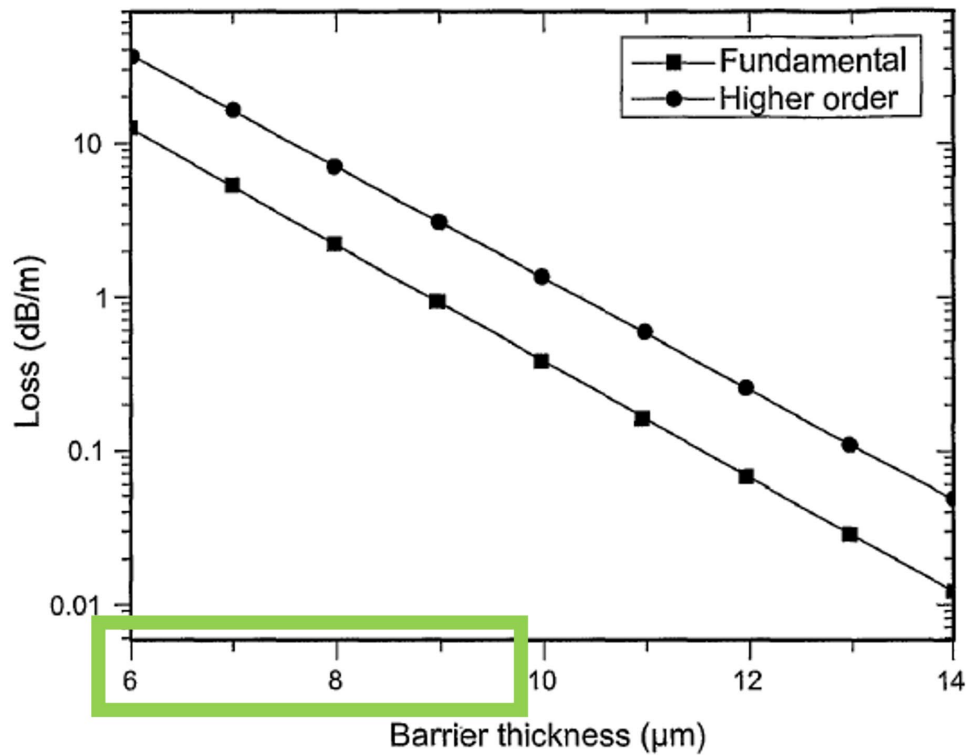


FIG. 2

EX1006, FIG. 2.

2. Reasons To Combine Neuberger And Davis Further With Kalle

131. A POSITA would have had numerous reasons to combine the core diameters and cladding thicknesses taught by Kalle with the system of Neuberger and Davis, which does not mention these dimensions, with a reasonable expectation of success. Kalle's output optical fiber is just like Neuberger's in that includes "a first core section 11 ..., a barrier layer 12 ..., a second core section 13 ..., and a cladding 14" EX1006, 15:21-23, claims 10, 24. Kalle's fiber also transmits light through its cores, just like Neuberger's. EX1006, 20:9-10. "[T]he optical signal

from the signal light source would be propagating in the **first core section 11** of the optical fiber 10.” EX1006, 20:23-25. “The pump light is **coupled** into the composite fiber formed by the first **core section 11** and at least the **second core 13** by a coupling means.” Light coupled to Kalle’s circular **first core 11** would output a circular beam and light coupled to Kalle’s ring-shaped **second core 13** would output a ring-shaped beam. The dimensions taught by Kalle—an **inner core** diameter between 10 μm and 100 μm , or between 30 μm and 60 μm (EX1006, 9:21-23, claims 10, 24), an **ring-shaped core** diameter that about 200 μm (EX1006, 21:19-20), and **intermediate cladding** thickness between 5 and 20 μm (EX1006, 13:2-3, 15:3-5, claims 11, 25) all fall within the ranges claimed by the ’054 Patent.

132. A POSITA would have found it obvious to apply Kalle’s dimensions to the system of Neuberger and Davis. *First*, other medical lasers at the time had similar dimensions to Kalle’s. In one case, lasers for gynecological sterilization had a total diameter below 600 microns. EX1008, 5:35-40 (“The light transmitting conduit 14A is preferably a single, flexible light transmitting fiber, such as used in fiberoptic devices, and generally has a total exterior diameter of about 600 microns or less.”). In a different case, the Food and Drug Administration approved the StrateFireTM Reusable Optical Fiber, which is used in general surgery to cut tissue and can be made to have diameters between 400 and 1,000 microns, in June 1997—more than a decade before the priority date for the ’054 Patent. Since both the

gynecological sterilization laser and the StrateFire™ Reusable Optical Fiber are directed to the same problem as Neuberger and have sub-millimeter total diameters, like Kalle, a POSITA would have found it obvious to use Kalle's core and cladding dimensions in the system of Neuberger and Davis. The combination would amount to nothing more than combining prior art elements (Kalle's dimensions and Neuberger and Davis' multi-clad optical fiber) to yield predictable results (a multi-clad optical fiber with Kalle's given dimensions that would be similar to known dimensions of other medical lasers at the time).

133. It would have been obvious for a POSITA to apply Kalle's core and cladding dimensions to Neuberger and Davis' system with a reasonable expectation of success.

3. Claim 15

- a) [15Pre] The method of claim 11, wherein the multi-clad fiber comprises an inner cladding between the inner fiber core and the at least one outer ring core, and wherein the multi-clad fiber is configured to have at least one of:
- b) [15A] the inner fiber core with a diameter of no greater than 200 μm ,
- c) [15B] the at least one outer ring core with a diameter of no greater than 600 μm , or
- d) [15C] the inner cladding with a thickness of no greater than 10 μm .

134. Neuberger in combination with Davis renders obvious [15Pre] for the reasons I provided in Section VIII.A.4.a) for [4A]. *See also* Section VIII.B.2 [Reasons To Combine Neuberger And Davis Further With Kalle].

135. Neuberger in combination with Davis and Kalle renders obvious [15A], [15B], and [15C] for the reasons I provided in Section VIII.B.1.b) for [5A], Section VIII.B.1.c) for [5B], and Section VIII.B.1.d) for [5C], respectively. *See also* Section VIII.B.2 [Reasons To Combine Neuberger And Davis Further With Kalle].

C. Ground III: Neuberger In Combination With Davis And Goell Renders Obvious Claims 6-8 And 16-18

1. Claim 6

- a) [6] The system of claim 1, wherein the multi-clad fiber comprises the **inner fiber core** with a **refractive index n_1** , a **first cladding** with a **refractive index n_2** , and an **outer ring core** with a **refractive index n_3** , and the **first cladding surrounds** the **inner fiber core** and is **between** the **inner fiber core** and the **outer ring core**, and wherein **$n_1=n_3$** and **$n_1>n_2$** .

136. Neuberger in combination with Davis and Goell renders obvious [6]. As I explained in Section VIII.A.6 [Ground 1, Claim 6], Neuberger in combination with Davis renders obvious [6]. In this Ground I further show that it was well-known to make output optical fibers with $n_1=n_3$.

137. Goell's Figure 1 shows a multicore output fiber that is just like Neuberger's. It features an **inner core** **surrounded by** an **inner cladding**, which is **surrounded by** an **outer ring core** that is further **surrounded by** an **outer cladding**, as I have colored below. See EX1007, claim 1 ("A multiple core optical fiber comprising: an **inner core** ...; an **inner cladding** of ... **surrounding** said **inner core** ...; at least one **outer core** ... **surrounding** said **inner core** ...; and at least one **outer cladding layer** ... **surrounding** said **outer core**").

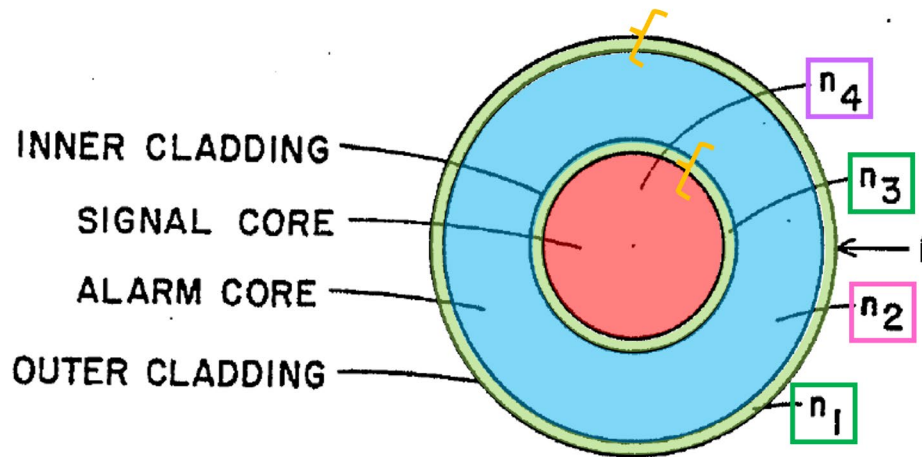


Fig. 1

EX1007, FIG. 1.

138. Goell teaches that the inner core and outer ring cores can have the same refractive index—*i.e.*, $n_1 = n_3$ (which in Goell's nomenclature is $n_4 = n_2$). See EX1007, claim 2 (“The fiber of claim 1 wherein said inner core and outer core have the same index of refraction.”).

2. Reasons To Combine Neuberger And Davis Further With Goell

139. A POSITA would have found it obvious apply Goell's teachings to the system of Neuberger and Davis by making Neuberger's inner and outer cores have the same refractive index. The output fibers in Neuberger and Goell both have the same structure: an inner core, an outer core, an inner cladding between the inner and outer cores, and an outer cladding surrounding the outer core. EX1004, [0021],

[0017]. EX1007, 2:23-44 (“An inner cladding layer of an index of refraction n_3 completely encloses the signal core for confining light energy within the signal core by the method of complete internal refraction since n_3 is chosen less than n_4 ... The alarm core is surrounded by an outer cladding layer having a refractive index n_1 which is slightly less than the refractive index n_2 of the alarm core. Light energy transmitting through the alarm core will be confined within the core since the inner cladding layer and outer cladding layer have lower indexes of refraction (n_3, n_1) than the index of refraction of the alarm core n_2 .”), 4:11-19 (“The concentric multiple core fiber shown in FIG. 1 can have several layers of signal cores and alternate layers of alarm cores or, alternatively, could have a series of signal cores each carrying separate information along distinct optical paths which are enclosed by one encompassing alarm core for providing security to all the signal cores contained within the fiber.”), claim 1 (“A multiple core optical fiber comprising... at least one outer core...”). EX1005, 4:51-61 (“[A]n optical beam 40 from an optical source 44... enters, via refraction, a core 46 of an optical fiber 50 (that includes a second core 48), in which the cores 46 and 48 are surrounded by a cladding 52... The terms ‘optical’ and ‘light’ are used broadly herein to encompass both visible and invisible electromagnetic radiation.”), 1:6-7 (“The present invention relates to dual-core and multicore optical fibers, and in particular, to the simultaneous accessibility of multiple cores in the same fiber.”), 2:59-61 (“[S]patially separated light sources may

be used to simultaneously launch electromagnetic radiation into different cores of a multiple-core fiber.”).

140. Each of the patents also teaches that the **inner core** and **outer core** transmit light while the claddings do not. Since the **inner core** and **outer core** generate output beams for different purposes, it is important to avoid cross-talk between the cores. To achieve this, the patents all explain that one must use a **higher refractive index material** for the cores and a **lower refractive index material** for the claddings that surround those cores so that light traveling through the cores does not leak into the claddings. EX1004, [0006] (“[A]ll incident radiation is advantageously reflected back into the optical fiber core.”); EX1007, 2:23-53 (“...Light energy transmitting through the alarm core will be confined within the cores since the inner cladding layer and outer cladding layer have lower indices of refraction...than the index of refraction of the alarm core...”). EX1005, 1:19-22, 2:65-3:2 (“[T]he index of refraction of the cladding is lower than the indices of refraction of the cores to confine optical beams within the cores.”), 2:24-27, 3:35-41, 3:48-53, claims 1-12.

141. It would have been obvious to a POSITA to apply Goell’s refractive index relationships to the system of Neuberger and Davis. Since the systems are both directed towards transmitting light through concentric cores and minimizing cross-talk between the cores, the combination amounts to nothing more than combining prior art elements (Goell’s refractive index relationships and Neuberger’s

outer core coupled to input fibers) according to known methods to yield the predictable result of the system of Neuberger and Davis in which the **inner core** and **outer core** have the **same index of refraction**, which is **greater than that of the claddings**). EX1004, [0026] (“[T]he cladding must have a smaller refractive index.”). EX1005, 2:67-3:2 (“[T]he index of refraction of the cladding is lower than the indices of refraction of the cores to confine optical beams within the cores.”), 3:20-27, 3:35-41, 3:49-53, 4:66-5:3, claims 1-12 EX1007, 1:40-42 (“An intermittent cladding layer of lower index material prevents an intermixing between the secret information and the security signal.”), 2:32-40 (“An inner cladding layer of an index of refraction n_3 completely encloses the signal core for confining light energy within the signal core by the method of complete internal refraction since n_3 is chosen less than n_4 ...The alarm core is surrounded by an outer cladding layer having a refractive index n_1 which is slightly less than the refractive index n_2 of the alarm core.”), 2:49-52 (“Light from one source can therefore travel through the signal core, and light from an independent source could travel through the alarm core with no interference or intermixing between the two light signals.”), claims 1, 2, and 4.

142. As I explained above in Section VIII.A.6 [Ground 1, Claim 6], a POSITA would have known that Neuberger’s fiber could have been made using the standard techniques outlined by Goell. EX1007, 1:62-2:2. (“[O]ne method for forming the multi-core fiber could consist in the successive application of a number

of layers of material by the process known as chemical vapor deposition ... [in which t]he material contributing to the higher index region [*i.e.*, cores] would be germania-silica glass, for example, and the material contributing to the lower index of refraction [*i.e.*, claddings] would be borosilicate glass.”) Such techniques were known for decades before the priority date of the '054 Patent and would have been obvious to use for a POSITA.

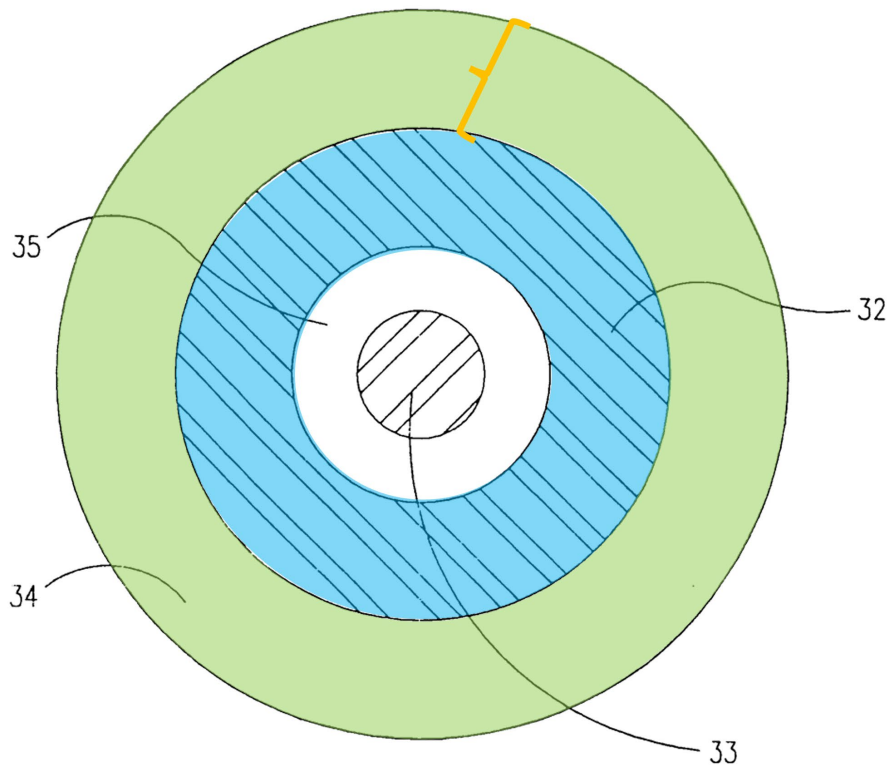
3. Claim 7

- a) [7] The system of claim 6, wherein the multi-clad fiber further comprises a **second cladding** **surrounding** the **outer ring core**, and wherein a **refractive index n_4** of the **second cladding** is **identical to** the **refractive index** of the **first cladding n_2** .

143. Neuberger and Davis render obvious the system of claim 6. *See* Section VIII.A.6 [Ground 1, Claim 6]. As I explained in Section VIII.A.7 [Ground 1, Claim 7], Neuberger in combination with Davis renders obvious [7]. In this Ground I further show that it was well-known to make output optical fibers with $n_2=n_4$.

144. As I have shown below, Neuberger's output fiber features a **second cladding—outer cladding 34—surrounding** the **outer ring core 32**.

FIGURE 3



EX1004, FIG. 3.

145. Figure 1 of Goell, which I have annotated below, shows an output fiber with the same structure: a **second cladding** **surrounding** an **outer core**. EX1007, 2:33-38. (“[A] **second core designated as an ‘alarm core’** is concentrically applied over both the inner cladding and the signal core... The **alarm core** is **surrounded by** an **outer cladding layer**.”) EX1007, claim 1. (“A multiple core optical fiber comprising:... at least one **outer core** of light transmissive material surrounding said inner core and cladding...; and at least one **outer cladding layer** of light transmissive material **surrounding** said **outer core**... .”)

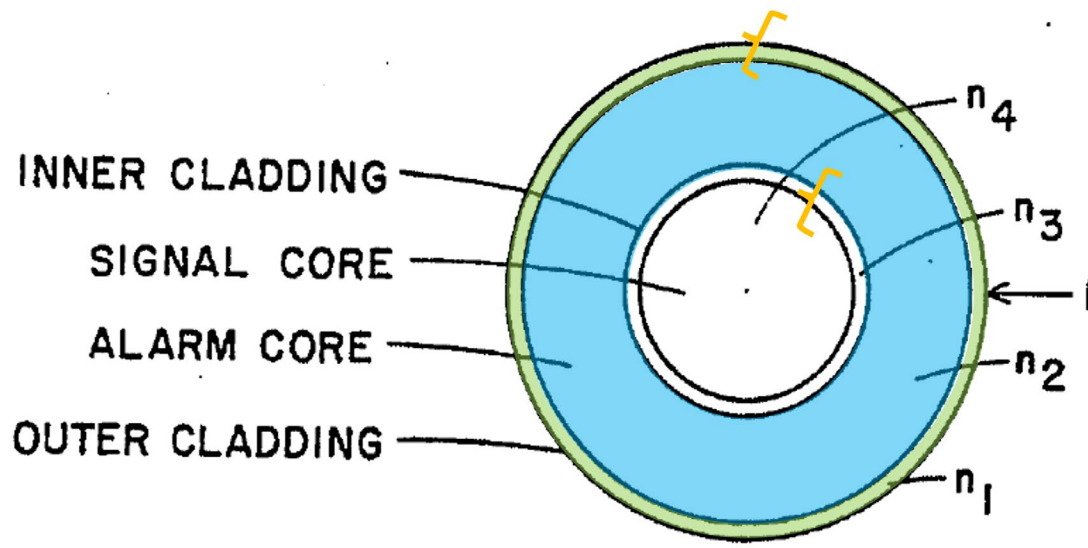


Fig. 1

EX1007, FIG. 1.

146. In Goell's system, the first cladding and the second cladding can have identical refractive indices. EX1007, claim 4 ("The fiber of claim 1 wherein said inner cladding and said outer cladding have the same index of refraction."). As I explained in Section VIII.C.2 [Reasons To Combine Neuberger And Davis Further With Goell], it would have been obvious to a POSITA to use Goell's refractive index relationships in the system of Neuberger and Davis.

147. A POSITA would have understood that they could make the multicore fiber in which the claddings have the same refractive index using techniques that were known for many decades before the priority date of the '054 Patent. Goell

explains that “[o]ne method for forming the multi-core fiber could consist in the successive application of a number of layers of material by the process known as chemical vapor deposition ... [in which t]he material contributing to the higher index region [*i.e.*, cores] would be germania-silica glass, for example, and the material contributing to the lower index of refraction [*i.e.*, claddings] would be borosilicate glass.” EX1007, 1:62-2:2. A POSITA would have known that making both the claddings out of the same borosilicate glass would result in both of the claddings having identical indices of refraction.

4. Claim 8

- a) [8] The system of 1, wherein the multi-clad fiber comprises **two or more outer ring cores**, and the system is configured to couple two or more corresponding input laser beams into the **two or more outer ring cores**.

148. As I explained above in Section VIII.A.8, Neuberger in combination with Davis renders obvious [8]. I further include Ground III to show that it was well-known in the art for a multicore fiber to include **two or more outer ring cores** that can be coupled to two or more corresponding input laser.

149. Figure 1a of Goell, which I have annotated below, shows “several layers of signal cores and alternative layers of alarm cores or, alternatively, ... a series of signal cores *each carrying separate information along distinct optical paths...*” EX1007, 4:11-19.

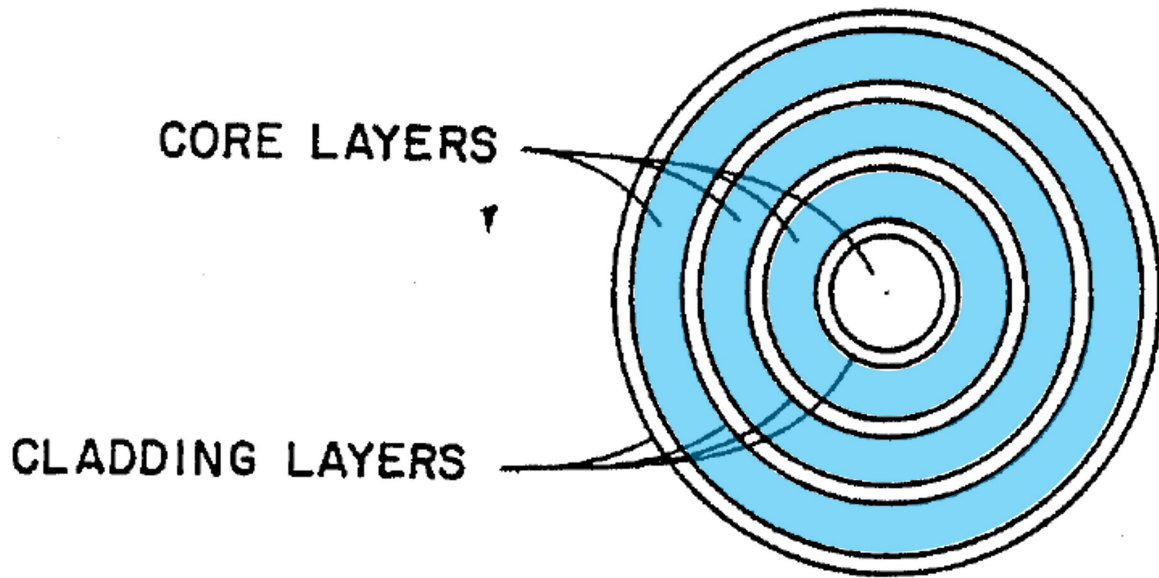


Fig. 1a

EX1007, Figure 1a.

150. Each of the concentric ring cores in Goell's system "carry[] separate information." EX1007, 4:11-19. This is just like Neuberger's teaching that one could use "additional concentric layers ... to transmit additional wavelengths." EX1004, [0017].

151. Using Goell's [multiple ring-shaped cores](#) with Neuberger's concentric core output fiber amounts to nothing more than combining prior art elements according to known methods to yield the predictable result of an optical fiber with [two or more outer rings](#). It would have been obvious for a POSITA to make this

combination given that Neuberger explicitly suggests that one might add additional concentric cores to transmit additional wavelengths through the output optical fiber. EX1004, [0017].

5. Claim 16

- a) [16] The method of claim 11, wherein the multi-clad fiber comprises the **inner fiber core** with a **refractive index n_1** , a **first cladding** with a **refractive index n_2** , and an **outer ring core** with **refractive index n_3** , and the **first cladding** **surrounds** the **inner fiber core** and is **between** the **inner fiber core** and the **outer ring core**, and wherein **$n_1 = n_3$** and **$n_1 > n_2$** .

152. Neuberger in combination with Davis and Goell renders obvious [16] for the reasons I provided in Section VIII.C.1 for [6]. *See also* Section VIII.C.2 [Reasons To Combine Neuberger And Davis Further With Goell].

6. Claim 17

- a) [17] The method of claim 16, wherein the multi-clad fiber further comprises a **second cladding** **surrounding** the **outer ring core**, and wherein a **refractive index n_4** of the **second cladding** is **identical** to the **refractive index** of the **first cladding n_2** .

153. Neuberger in combination with Davis and Goell renders obvious [17] for the reasons I provided in Section VIII.C.3 for [7]. *See also* Section VIII.C.2 [Reasons To Combine Neuberger And Davis Further With Goell].

7. Claim 18

- a) [18] The method of claim 11, wherein the multi-clad fiber comprises **two or more outer ring cores**, and the method comprises: coupling two or more corresponding input laser beams into the **two or more outer ring cores**.

154. Neuberger in combination with Davis and Goell renders obvious [18] for the reasons I provided in Section VIII.C.4 for [8]. *See also* Section VIII.C.2 [Reasons To Combine Neuberger And Davis Further With Goell].

D. Ground IV: Neuberger In Combination With Davis In Further Combination With Lai Renders Obvious Claims 9-10 And 19-20

1. Claim 9

- a) [9] The system of claim 1, wherein the system is configured to generate an **output laser beam with a power of at least 1 kW**.

155. Neuberger and Davis render obvious the system of claim 1. *See* Section VIII.A.1 [Ground 1, Claim 1]. Neuberger, Davis, and Lai further render obvious the added limitations of [9].

156. The output fiber in Neuberger's system is used for medical applications such as cutting, ablating, coagulating, or vaporizing tissues. EX1004, [0011], [0012] ("Another object of the present invention is to provide a medical diode laser system that allows for simultaneous coagulation, and cutting or ablating of tissue."), [0017] ("The present invention provides a device that allows for concurrent transmission of

at least two wavelengths or at least two power densities which can for example simultaneously cut or vaporize and coagulate tissue.”).

157. Figure 5 of Lai, which I have annotated below, shows a dual-wavelength surgical laser system. EX1010, [0084] (“Laser system 500 is a dual-wavelength surgical laser system consisting of a laser 510 for tissue explosive ablation and a laser 520 for tissue coagulation.”)

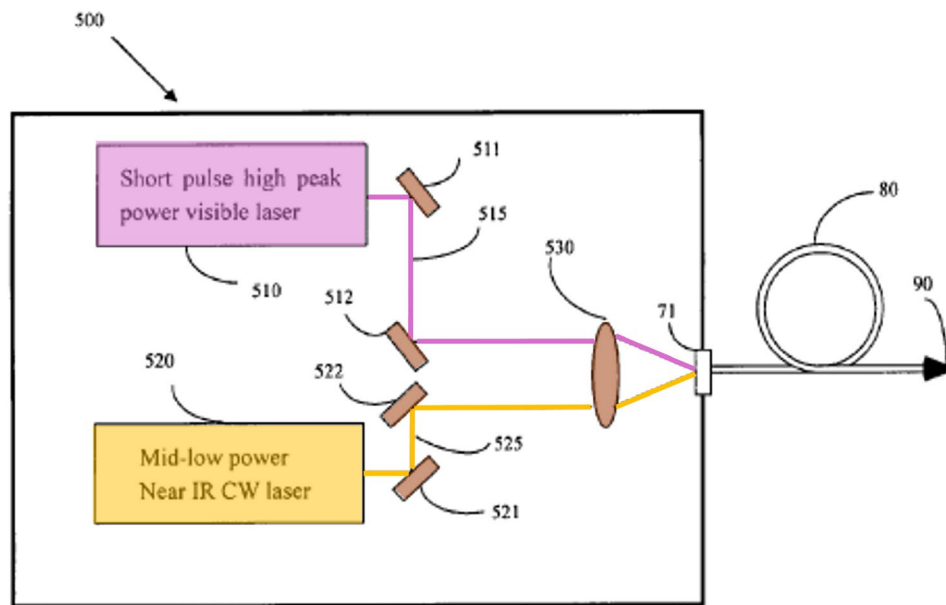


Figure 5

EX1010, FIG. 5

Like Neuberger and Davis, Lai uses both solid-state and diode lasers. EX1004, [0002] (“***Solid state lasers, such as the Nd:YAG***, have primarily been employed to achieve the desired optical power and wavelength for medical procedures in the fields of dermatology, plastic surgery, ophthalmology,

otolaryngology, neurological surgery, gastroenterology, urology, gynecology, and general surgery. ... **Diode lasers** are attractive substitutes for these solid state lasers because diode lasers are cheap, small, and have low power requirements. ... To obtain effective power, these lasers are typically combined to form an array on one or more substrates.”), EX1005, 4:51-56 (“One embodiment of the invention is illustrated in FIG. 3A, in which an optical beam 40 from an optical source 44 (such as *a laser diode*, a Ti:Sapphire laser, *a Nd:YAG laser*, or the like) enters, via refraction, a core 46 of an optical fiber 50 (that includes a second core 48), in which the cores 46 and 48 are surrounded by a cladding 52.”). The lasers used in Lai’s system for tissue ablation can reach output powers of 60-200 kW. See EX1010, [0084] (“The laser 510 can be either [diode-pumped solid state] laser system 100, 200, 300, or 400. The laser 520 can be continuous wave 1064 nm Nd:YAG laser, ... 800-1000 nm diode laser, 800-100[0] nm fiber-coupled diode laser,... For best hemostasis, the laser 520 shall have 5-30 W average power on target tissues.”), [0062] (“The laser system 100 is a *diode-pumped Nd:YAG laser*.”), [0065] (“To obtain laser pulses with pulse width less than 150 ns and **output peak power 60-200 kW** at 532 nm, the Nd:YAG laser rod shall have a small diameter between 2 mm to 5 mm.”), [0073] (“All combined efforts enable the laser system to produce sub-150 ns pulses with higher than **60 kW peak power** at 532 nm.”).

2. Reasons To Combine Neuberger And Davis Further With Lai

158. A POSITA would have been motivated to combine Neuberger and Davis with Lai with a reasonable expectation of success. **First**, Lai and Neuberger are both focused on the same problem: making surgical lasers that can output a beam for cutting or ablating tissue and a separate beam for coagulating tissue. *See* EX1004, [0011], [0012] (“Another object of the present invention is to provide a medical diode laser system that allows for simultaneous coagulation, and cutting or ablating of tissue.”), [0017] (“The present invention provides a device that allows for concurrent transmission of at least two wavelengths or at least two power densities which can for example simultaneously cut or vaporize and coagulate tissue.”); EX1010, [0084] (“Laser system 500 is a dual-wavelength surgical laser system consisting of a laser 510 for tissue explosive ablation and a laser 520 for tissue coagulation.”).

159. Lai, Neuberger, and Davis also all use the same kinds of input beams: diode lasers and Nd:YAG lasers. EX1004, [0002] (“Solid state lasers, ***such as the Nd:YAG***, have primarily been employed to achieve the desired optical power and wavelength for medical procedures.... ***Diode lasers*** are attractive substitutes...”); EX1005, 4:51-57 (“optical source 44 (such as a ***laser diode***, ... a ***Nd:YAG laser***, or the like)...”); EX1010, [0062] (“The laser system 100 is a ***diode-pumped ND:YAG***

laser ...”), [0084] (“The laser 510 can be either laser system 100... The laser 520 can be continuous wave 1064 nm *Nd:YAG laser*, ... 800-1000 nm *diode laser*, ...”).

160. Additionally, Lai and Neuberger both teach the use of both pulsed and continuous lasers for surgical applications. *See* EX1004, [0011], [0012] (“Another object of the present invention is to provide a medical diode laser system that allows for simultaneous *coagulation, and cutting or ablating of tissue*.”), [0017] (“The present invention provides a device that allows for concurrent transmission of at least two wavelengths or at least two power densities which can for example *simultaneously cut or vaporize and coagulate tissue*.”); EX1010, [0084] (“Laser system 500 is a dual-wavelength surgical laser system consisting of *a laser 510 for tissue explosive ablation and a laser 520 for tissue coagulation*.”). Indeed, just like Neuberger, Lai teaches that either continuous or pulsed lasers can be utilized. EX1004, [0029] (“In yet another embodiment of the present invention pulsed laser radiation is used for ablation, and continuous wave radiation is used for coagulation purposes. ... In this alternative, the **inner core area** (in the concentric core arrangement described above) is used to transmit the pulsed radiation, while the surrounding **outer core** carries the continuous wave radiation.”), claim 4 (“wherein said radiation from a first source is pulsed and from a second source is a continuous wave.”); EX1010, [0062], [0084] (“The laser 510 can be either [diode-pumped Nd:YAG] laser system 100, 200, 300, or 400 [that is quasi-CW Q-switched and

intracavity-frequency-doubled to produce a laser output 90 of short pulses and high pulse fluence]. The laser 520 can be continuous wave 1064 nm Nd:YAG laser, ... 800-1000 nm diode laser...). The combination of Lai with the system of Neuberger and Davis therefore amounts to nothing more than combining prior art elements—Neuberger’s multicore output fiber that transmits diode and Nd:YAG lasers and generates different beams for different surgical applications and Lai’s surgical laser that transmits diode and Nd:YAG laser beams with output powers in the kilowatt range—to yield predictable results—Neuberger’s multicore output fiber that generates diode and Nd:YAG output beams with powers above 1 kW.

161. **Second**, while Neuberger discusses the importance of surgical lasers for tissue cutting, ablation, coagulation, and vaporization, Neuberger does not mention the necessary output power for a laser that performs each of these tasks. Lai explains that for prostate surgery, the laser beam must have an output power in the kilowatt range. EX1010, [0025] (“The present invention also contemplates to employ two AO Q-switches of one EO Q-switch to obtain shorter pulse duration of 40 ns to 150 ns and to obtain higher peak power of 50 kW to 100 kW, leading to a pulse fluence of 250 mJ/cm² to 1000 mJ/cm² on target tissues.”). The combination is therefore nothing more than a teaching, suggestion, or motivation in the prior art—Lai’s guidance that prostate surgery requires lasers with output powers of 50 kW to 100 kW—that would have lead a POSITA to modify a prior art reference—

Neuberger's surgical laser system—to arrive at the claimed invention—a multicore output fiber for laser surgeries that transmits Nd:YAG lasers with output powers far above 1 kW.

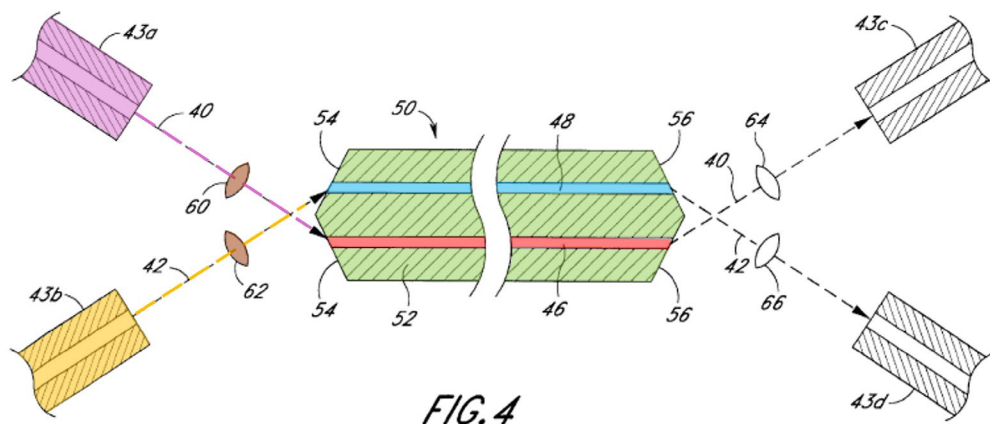
3. Claim 10

- a) [10Pre] The system of claim 1, further comprising a **switchable device** **coupled between** the **first** and **second** optical fibers and the multi-clad fiber,
- b) [10A] wherein the **switchable device** is configured to **electively couple** the **first input laser beam** at least into the **inner fiber core** of the multi-clad fiber and the **second input laser beam** at least into the at least one **outer ring core** of the multi-clad fiber.

162. Neuberger and Davis render obvious the system of claim 1. *See* Section VIII.A.1. Neuberger in combination with Davis further in combination with Lai renders obvious [10].

163. As I discussed above in Section VIII.A.1 [Ground 1, Claim 1], Neuberger does not explain how input laser beams would be guided to the **inner core** or **outer core** of its multicore output fiber that transmits beams with different beam characteristics for various surgical applications. EX1004, [0002]. However, Davis teaches a **coupling** technique that involves using “optical elements such as **lenses 60 and 62**... to focus the optical beams **40** and **42** onto the individual cores **46** and **48**.” EX1005, 5:43-45; *see also* EX1005, 5:58-65 (describing that “**lenses 60 and 62** can be any type of focusing optical elements,” can “refer to either **one kind of lens** or a

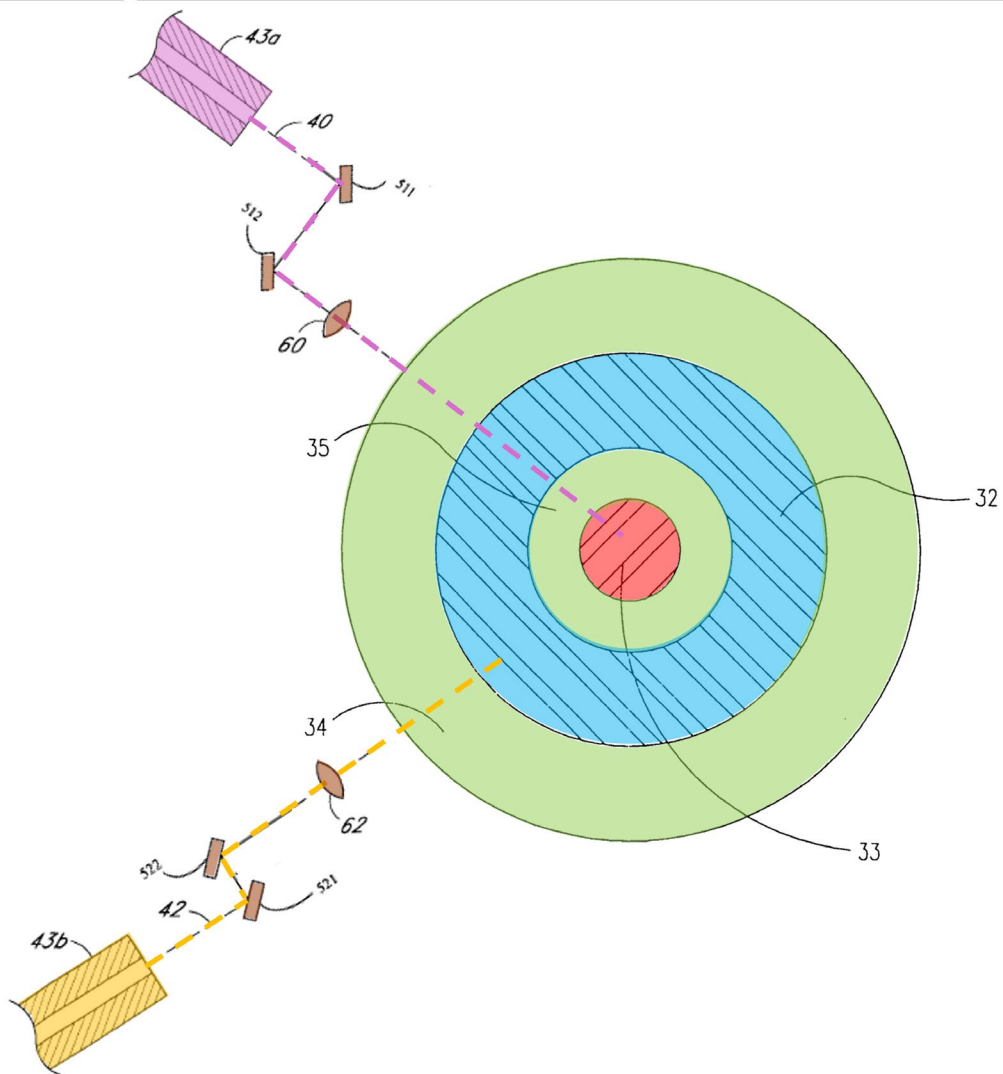
combination of lenses,” and can be “close enough” to fiber 50 to focus the beams onto their respective cores). Davis’ lenses sit upon “mechanical mounts resting upon translation stages” that allow the lenses to move, which enables electively coupling the optical beams into different cores. EX1005, 5:46-50 (“[T]he various optical components may be fixed, for example, within respective mechanical mounts resting upon respective translation stages to control the alignment of the optical beams 40 and 42, which propagate along optical paths within the cores 46 and 48.”).



EX1005, FIG. 4

164. Lai also teaches that optical elements such as mirrors can electively couple different input beams into the fiber end of Neuberger’s multicore output fiber. For example, an input beam 40 from a first source 43a can be coupled to Neuberger’s inner core 33 using an optical switching system comprised of mirrors lens 60 and mirrors 511 and 512. A different input beam 42 from a different source

43b can be coupled to Neuberger's outer ring core 32 using an optical switching system comprised of lens 62 and mirrors 521 and 522. EX1010, [0084] ("The output beam [40] from the laser [43a] propagates in free space and is guided by tuning mirrors 511 and 512 to fiber coupling lens [60]. The output beam [42] from the laser [43b] propagates in free space and is guided by tuning mirrors 521 and 522 to focal lens [62]. After focal lens [60 or 62], the beam [40] and beam [42] are both coupled into [output fiber]."). I have illustrated this combination below.



Combination of EX1010, FIG. 5, EX1005, FIG. 4-6, and EX1004, FIG. 3

165. A POSITA would have found it obvious to use Lai's coupling techniques with the system of Neuberger and Davis. While Davis' technique uses a single lens 60 or 62 to couple each of the input beams 40 and 42 from the input laser sources 43a and 43b to Neuberger's inner core fiber 33 and outer core fiber 32, Lai teaches that the switching system may involve mirrors as well as lenses. A POSITA

would have known that using mirrors in the system of Neuberger and Davis would be a very simple addition.

4. Claim 19

- a) [19] The method of claim 11, wherein the **output laser beam has a power of at least 1 kW.**

166. Neuberger in combination with Davis in further combination with Lai renders obvious [19] for the reasons I provided in Section VIII.D.1 for [9]. *See also* Section VIII.D.2 [Reasons To Combine Neuberger And Davis Further With Lai].

5. Claim 20

- a) [20Pre] The method of claim 11, wherein **coupling** the **first input laser beam** and the **second input laser beam** into the fiber end of the multi-clad fiber comprises: **electively coupling**, by a **switchable device coupled** between the **first** and **second optical fibers** and the fiber end of the multi-clad fiber, one of the **first input laser beam** at least into the **inner fiber core** of the multi-clad fiber and the **second input laser beam** at least into the at least one **outer ring core** of the multi-clad fiber.

167. Neuberger in combination with Davis in further combination with Lai renders obvious [20] for the reasons I provided in Section VIII.D.3 for [10]. *See also* Section VIII.D.2 [Reasons To Combine Neuberger And Davis Further With Lai].

IX. CONCLUSION

168. It is my opinion that the challenged claims 1–20 of the '054 Patent are unpatentable.

X. AVAILABILITY FOR CROSS-EXAMINATION

169. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross examination in the case and that cross examination will take place within the United States. If cross examination is required of me, I will appear for cross examination within the United States during the time allotted for cross examination.

XI. RIGHT TO SUPPLEMENT

170. I reserve the right to supplement my opinions in the future to respond to any arguments that Patent Owner may raise and to take into account new information as it becomes available to me.

XII. JURAT

171. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code.

Dated: February 20, 2026



Dr. Liang Dong

APPENDIX A

RESUME – Liang Dong

PERSONAL DATA

Professor

Department of Electrical and Computer Engineering, Clemson University, Clemson, SC 29634, 864-656-1160

EDUCATION

Ph.D., University of Southampton, 1992, Fiber Optics

M.S., University of Manchester Institute of Science and Technology, 1987, Telecommunications and Digital Electronics

B.S., Harbin Institute of Technology, 1985, Electronics

PROFESSIONAL EXPERIENCE

Clemson University, 2017-present, Professor

Clemson University, 2010-2017, Associate Professor

IMRA America Inc., 2003-2010, Senior Technical Manager

Lightwaves2020 Inc., 2002-2003, Research Director

Attolight Inc., 2001-2003, Founder

Corvis Corp., 2000-2001, Technical Manager

Corning Inc., 1998-2000, Senior Scientist/Project Manager

University of Southampton, 1992-98, Research Fellow

MEMBERSHIPS

Fellow/Life member, Optica (formerly the Optical Society of America, OSA), 2014

Fellow/Life member, International Society of Optical Engineering (formerly the Society of Photographic Instrument Engineers, SPIE), 2017

Fellow, Institute of Electrical and Electronics Engineers (IEEE), 2019

CITATIONS

Google scholar: citations= 12466, h-index=61 (all), i10-index=179, Dec. 2025

RESEARCH EXPENDITURE

Year	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020
Expenditure	\$380,362	\$584,565	\$707,150	\$765,011	\$1,219,638	\$949,926	\$665,828	\$425,400	\$433,817	\$400,058
Year	2020-2021	2021-2022	2022-2023	2023-2024	2024-2025					
Expenditure	\$423,906	\$522,529	\$598,988	664,898	666,488					

Total research expenditure: \$9,408,564

Average per year between 2010-2025: \$627,238

DIRECT DRESEARCH GRANTS

Project	Title	Total	Role	From
2010001624	Advanced Optical Fibers for High Power Fiber Lasers	\$2,356,840	PI	Joint Technology Office
2011000617	Large Core All-Solid Photonic Bandgap Fibers	\$50,000	PI	Northrop Grumman
2011000727	Polarization-Maintaining Large-Core All-Solid Photonic Bandgap Fibers for Power Scaling of High-Power Fiber Lasers	\$791,826	PI	Missile Defense Agency
2012000824	Novel Fiber Concepts for High Power Single Mode Fiber Lasers	\$2,460,000	PI	Joint Technology Office
2014001189	Advanced Optical Fiber Development for Fiber Lasers with Sub-GHz Linewidth	\$300,000	PI	Army Research Office
2014001255	Optimization of TM-Doped Phosphosilicate Glass for High Power Fiber Lasers	\$100,000.00	PI	Air Force Research Laboratory
2015000197	Advanced Optical Fiber Development for kW Fiber Lasers with Sub-GHz Linewidth	\$108,000.00	PI	Aary Research Office
2015001528	All-solid Photonic Bandgap Fibers for kW-level Narrow-Linewidth Single-mode CW Fiber Lasers	\$1,100,000	PI	Joint Technology Office
2016000557	Silicate Glass PWG Development	50,000.00	PI	Raytheon
2017000450	Tm-doped Photonic Bandgap Fibers Continuation of W911NF-12-1-0332	\$61,994	PI	Air Force Research Laboratory
2017001402	Power Scaling of Combinable Fiber Lasers to Beyond 5kW	\$599,999	PI	Army Research Office
2018000816	Power Scaling of Combinable Fiber Lasers to Beyond - REU	\$15,000	PI	Army Research Office
2018000988	A Study of Single-Frequency MOPA Based on Fiber Lasers for Starshot	\$149,838	PI	Breakthrough Starshot
2019001858	Hollow-core MWIR Optical Fibers	\$199,123	PI	Army Research Office
2021000945	Intrinsically SBS Suppressive Fiber Amplifiers for Future Directed Energy Weapons Systems	\$272,000	PI	AFOSR
2022000971	Hollow-core MWIR Optical Fibers	\$200,000	PI	Army Research Office
2023001833	Advanced Laser Systems TASK ORDER 2.1	\$326,913	PI	Strategic Missile Defense Command
2025001125	Efficient High-Power Diffraction-Limited Fiber Lasers with Ultra-Low Quantum Defect	\$511,354	PI	Army Research Office
2011000300	DURIP: Acquisition of Fabrication Equipment for High Power Laser Research	\$150,000	Co-PI	Army Research Office
2017000269	A Unified Materials Approach to Mitigating Nonlinearities in HEL Optical Fibers	1,660,891	Co-PI	Joint Technology Office

2021001415	Advanced Laser Systems	\$4,991,570	Co-PI	Strategic Missile Defense Command
20222001893	Advanced Laser Systems II	\$5,387,500	Co-PI	Strategic Missile Defense Command
2024000239	Advanced Laser Systems III	\$4,033,823	Co-PI	Strategic Missile Defense Command
2024001406	Understanding Nano-Engineered Optical Fibers for Power-Scaled Fiber Lasers	\$429,360	Co-PI	Air Force Research Laboratory
2025000864	Advanced Laser Systems	\$4,218,452	Co-PI	Strategic Missile Defense Command

TOTAL RESEARCH GRANTS Allocated to Liang Dong: \$10,356,395

TOTAL RESEARCH GRANTS: \$30,524,483

PROFESSIONAL ACTIVITIES

Currently active:

Topical editor, Optics Lettes, (June 2025-)

No longer active:

OSA Advanced Photonics Congress Strategy Steering Committee (2019-2024)

Workshop on Specialty Optical Fibers Steering Committee (2019)

SPIE Photonic Europe, Programme Committee (2019)

Optica, Associate editor (2014-2020)

Program committee, Fiber Lasers, PhotonicsWest (2017-2021)

OSA Specialty Optical Fiber Topical Meeting, General Chair (2015-2019)

Workshop on Specialty Optical Fibers, General chair (2019)

Program chair, Fiber Lasers, SPIE PhotonicsWest (2019)

International Advisory Committee, International Conference on Fiber Optics and Photonics (2018)

Program co-chair, Fiber Lasers, PhotonicsWest (2017-2019)

Technical committee, Conference on Lasers and Electro-Optics (2014-2018)

Workshop on Specialty Optical Fibers, International Steering Committee (2017)

NSF Panel on Photonics Integration (2017)

OSA Specialty Optical Fiber Topical Meeting, Program Chair (2010-2016)

IEEE Journal of Quantum Electronics, Associate Editor (2009-2016)

Technical committee, Micro-structure and Specialty Optical Fibre Conference, Photonics Europe (2015-2016)

Workshop on Specialty Optical Fibers, Program chair (2014-2015)

International Photonics and OptoElectronics Meetings (POEM), Fiber-Based Technologies and Applications (FBTA), conference co-chair, (2014)

OptoElectronics and Communications Conference, Technical committee (2014)

Technical Committee Member, Photonics Global Conference, (2012-2013)

Technical Committee Member, OSA Advanced Solid-State Photonics (2011-2013)

Technical Committee Member, Optical Fiber Communications Conference (2011-2014)

Teach SPIE short course on Fiber Lasers and their Applications (SC1105) (2013)

Workshop on Specialty Optical Fibers, Member of Technical Committee (2010-2013)

NSF SBIR Panel on Optical Materials (2011)

Optical Fiber Technology, Guest Editor (2009-2011)

IEEE Photonics Society Winter Topical Meeting, Member of Technical Committee (2010)

OptoElectronics and Communications Conference, Workshop Chair (2009)

IEEE Photonics Technology Letters, Associate Editor (2000-2003)

Bragg Gratings, Photosensitivity and Poling in Glass Waveguides, Member of Technical Committee (2000)

PUBLICATIONS

Books and Book chapters

1. Edited by Dan Hewak, *Properties, Processing and Applications of Glass and Rare Earth-Doped Glasses for Optical Fibres*, (1998), Chapter A4.2 *Drawing of silica optical fibres*, Institution of Engineering and Technology. ISBN-10: 085296952X, ISBN-13: 978-0852969526.

2. Edited by Christophe Lethien, *Optical Fiber, New Developments, Chapter 24 Micro-structured All Glass Optical Fibers*, (2009), In-tech, Vukovar. SBN 978-953-7619-50-3.
3. Edited by Hagop Injeyan, *High Power Laser Handbook, (2011), Chapter 15 Introduction to Fiber Lasers*, McGraw-Hill. ISBN-10: 0071609016, ISBN-13: 978-0071609012.
4. Edited by Boris Denker and Eugene Shklovsky, *Handbook of Solid-State Lasers, (2012), chapter 15 Fiber Lasers*, Woodhead Publishing Ltd. ISBN 0 85709 272 3, ISBN-13: 978 0 85709 272.
5. Edited by Moh Yasin, Hamzah Arof and Sulaiman Wadi Harun, *Advances in Optical Fiber Technology: Fundamental Optical Phenomena and Applications, chapter 7 Advanced Optical Fibers for High power Fiber lasers*, Intech, ISBN 978-953-51-1742-1, Published: February 25, 2015.
6. Liang Dong and Bryce Samson, *Fiber Lasers: Basics, Technology and Applications*, CRC Press, ISBN-10: 1498725546, ISBN-13: 978-1498725545, 2017.

Refereed Journal Publications

1. M.E. Fermann, L. Li, M.C. Farries, L.J. Poyntz-Wright and L. Dong, "Second-harmonic generation using gratings optically written by mode interference in poled optical fibers", *Optics Letters* **14**, 748-750(1989).
2. C.D. Hussey, T.A. Birks, A.M. Wingfield, A. Niu, R. Kenny and L. Dong, "Rectangular mode transformers in tapered single-mode fibers", *Electronics Letters* **25**, 1419-1420(1989).
3. H. Sabert, L. Dong and P.St.J. Russell, "Versatile accousto-optical flexural wave modulator, filter and frequency shifter in dual-core fiber", *International Journal of Optoelectronics* **7**, 189-194(1992).
4. L. Dong, P.J. Wells, D.P. Hand and D.N. Payne, "Photosensitivity in Ce³⁺-doped optical fibers", *Journal of the Optical Society of America* **10**, 89-93(1993).
5. L. Dong, T.A. Birks, M.H. Ober and P.St.J. Russell, "Intermodal coupling by periodic microbending in dual-core fibers: comparison of experiment and theory", *Journal of Lightwave Technology* **12**, 24-27(1994).
6. L. Dong, J.L. Archambault, L. Reekie, P.St.J. Russell and D.N. Payne, "Bragg gratings written in Ce³⁺-doped fibers by a single excimer pulse", *Optics Letters* **18**, 861-863(1993).
7. R.I. Laming, J.D. Minelly, L. Dong and M.N. Zervas, "Twin-core erbium-doped fiber amplifier with passive spectral gain equalization", *Electronics Letters* **29**, 509-510(1993).
8. L. Dong, J.L. Archambault, L. Reekie, P.St.J. Russell and D.N. Payne, "Single pulse Bragg gratings written during fiber drawing", *Electronics Letters* **29**, 1577-1578(1993).
9. P.G. Kazansky, L. Dong and P.St.J. Russell, "High second-order nonlinearities in poled silicate fibers", *Optics Letters* **19**, 701-703(1994).
10. L. Dong, J. Pinkstone, P.St.J. Russell and D.N. Payne, "Ultraviolet absorption in modified chemical vapor deposition preforms", *Journal of the Optical Society of American B*, **11**, 2106-2111(1994).
11. P.G. Kazansky, L. Dong and P.St.J. Russell, "Vacuum poling: an improved technique for effective thermal poling of silica glass and germanosilicate fibers", *Electronics Letters* **30**, 1345-1347(1994).
12. D.J. Richardson, R.P. Chamberlain, L. Dong and D.N. Payne, "Experimental demonstration of 100 GHz dark soliton generation and propagation using a +GVD dispersion decreasing fiber", *Electronics Letters* **30**, 1326-1327(1994).
13. L. Dong, J.L. Archambault, L. Reekie, P.St.J. Russell and D.N. Payne, "A study of photo-induced absorption change in germanosilicate preforms: evidence for the color-centre model of photosensitivity", *Applied Optics* **34**, 3436-3440(1995).
14. P.G. Kazansky, P.St.J. Russell, L. Dong and C.N. Pannell, "Pockel's effect in thermally poled silica optical fibers", *Electronics Letters* **20**, 843-845(1995).
15. D.J. Richardson, R.P. Chamberlain, L. Dong, D.N. Payne, A.D. Ellis, T. Widdowson, and D.M. Spirit, "Demonstration of 205km transmission of 35GHz, 5ps pulses generation from a diode-driven, low jitter, beat-signal to soliton conversion source", *Electronics Letters* **31**, 470-472(1995).
16. L. Dong, J.L. Archambault, E. Taylor, M.P. Roe, L. Reekie and P.St.J. Russell, "Photosensitivity in tantalum-doped silica optical fibers", *Journal of the Optical Society of America B* **12**, 1747-1750(1995).
17. M.G. Xu, L. Dong, L. Reekie, J.A. Tucknott and J.L. Cruz, "Temperature-independent strain sensor using a chirped Bragg grating in a tapered fiber", *Electronics Letters* **31**, 823-825(1995).
18. L. Dong, J.L. Cruz, L. Reekie and J.A. Tucknott, "Fabrication of chirped fiber gratings using etched tapers", *Electronics Letters* **25**, 908-909(1995).
19. L. Dong, J.L. Cruz, L. Reekie and J.A. Tucknott, "Chirped fiber Bragg gratings fabricated using etched tapers", *Optical Fiber Technology* **1**, 363-368(1995).
20. L. Dong, J.L. Cruz, L. Reekie and J.L. Archambault, "Tuning and chirping fiber Bragg gratings by deep etching", *IEEE Photonics Technology Letters* **7**, 1433-1435(1995).
21. L. Dong, J.L. Cruz, J.A. Tucknott, L. Reekie and D.N. Payne, "Strong photosensitive gratings in tin-doped phosphosilicate optical fibers", *Optics Letters* **20**, 1982-1984(1995).
22. L. Dong, J.L. Cruz, L. Reekie, M.G. Xu and D.N. Payne, "Enhanced photosensitivity in tin co-doped germanosilicate optical fibers", *Photonics Technology Letters* **7**, 1048(1995).

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24. D. Taverner, D.J. Richardson, M.N. Zervas, L. Reekie, L. Dong and J.L. Cruz, "Investigation of fiber grating based performance limits in pulse stretching and recompression schemes using bidirectional reflection from a linearly chirped fiber grating", *IEEE Photonics Technology Letters* **7**, 1436-1438(1995).
25. D.J. Richardson, R.P. Chamberlin, L. Dong and D.N. Payne, "High quality soliton loss-compensating in 38km dispersion decreasing fiber", *Electronics Letters* **31**, 1681-1682(1995).
26. A.D. Ellis, W.A. Pender, T. Widdowson, D.J. Richardson, R.P. Chamberlain and L. Dong, "All-optical modulation of 40 GHz beat frequency conversion soliton source", *Electronics Letters* **31**, 1362-1364(1995).
27. O.C. Graydon, W.H. Loh, R.I. Laming and L. Dong, "Triple-frequency operation of an Er-doped twincore fiber loop laser", *IEEE Photonics Technology Letters* **8**, 63-64(1996).
28. J.L. Cruz, L. Dong and L. Reekie, "Improved thermal sensitivity of fiber Bragg gratings using a polymer overlayer", *Electronics Letters* **32**, 385-387(1996).
29. J.L. Cruz, L. Dong, S. Barcelos and L. Reekie, "Fiber Bragg gratings with various chirp profiles made in etched tapers", *Applied Optics* **35**, 6781-6787(1996).
30. D.J. Richardson, L. Dong, R.P. Chamberlin, A.D. Ellis, T. Widdowson and W.A. Pender, "Periodically amplified system based on loss compensating dispersion decreasing fiber", *Electronics Letters* **32**, 373-374(1996).
31. C.V. Poulsen, O.C. Graydon, R.I. Laming, M.N. Zervas and L. Dong, "Self-regulating spectral characteristics of four channel WDM link utilizing twincore erbium doped fiber amplifier", *Electronics Letters* **32**, 2166-2168(1996).
32. L. Dong, P. Hua, T.A. Birks, L. Reekie and P.St.J. Russell, "Novel Add/drop filters for wavelength-division-multiplexing optical fiber systems using a Bragg grating assisted mismatched coupler", *Photonics Technology Letters* **8**, 1656-1658(1996).
33. W.H. Loh, L. Dong and J.E. Caplen, "Single-sided output Sn/Er/Yb distributed feedback fiber lasers", *Applied Physics Letters* **69**, 2151-2153(1996).
34. L. Dong, W.F. Liu and L. Reekie, "Negative index gratings formed by 193 nm excimer laser", *Optics Letters* **21**, 2032-2034(1996).
35. L. Dong, L. Reekie, J.L. Cruz, J.E. Caplen, J.P. de Sandro and D.N. Payne, "Optical fibers with depressed claddings for suppression of coupling into cladding modes in fiber Bragg gratings", *Photonics Technology Letters* **9**, 64-66(1997).
36. L. Dong, W.H. Loh, J.E. Caplen, J.D. Minelly and L. Reekie, "Efficient single frequency fiber lasers using novel photosensitive Er/Yb optical fibers", *Optics Letters* **22**, 694-696(1997).
37. J.L. Cruz, A. Diez, M.V. Andres, A. Segura, B. Ortega and L. Dong, "Fiber Bragg gratings tuned and chirped using magnetic fields", *Electronics Letters* **33**, 235-236(1997).
38. K. Hsu, W.H. Loh, L. Dong and C.M. Miller, "Efficient and tunable DBR Er/Yb fiber lasers", *Journal of Lightwave technology* **15**, 1438-1441(1997).
39. J.L. Cruz, B. Ortega, M.V. Andrés, B. Gimeno, D. Pastor, J. Capmany and L. Dong, "Chirped fiber Bragg gratings for phased-array antennas", *Electronics Letters* **33**, 544-545(1997).
40. L. Dong and W.F. Liu, "Thermal decay of fiber gratings of positive and negative index changes formed at 193 nm in a boron-codoped germanosilicate fiber", *Applied Optics* **36**, 8222-8226(1997).
41. L. Reekie and L. Dong, "Mechanisms of grating formation in optical waveguides", *Current Opinion in Solid State & Material Science* **2**, *invited paper*, 200-203(1997).
42. D. Taverner, D.J. Richardson, L. Dong, J.E. Caplen, K. Williams, R.V. Penty, "158μ pulses from a single transverse mode, large mode-area EDFA", *Optics Letters* **22**, 378-380(1997).
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44. L. Dong, M.J. Cole, A.D. Ellis, R.I. Laming and T. Widdowson, "40 Gbit/s 1.55 μm return-to-zero transmission over 109 km of non-dispersion shifted fiber with long continuously chirped fiber gratings", *Electronics Letters* **33**, 1563-1565(1997).
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57. J.L. Cruz, B. Ortega, M.V. Andrés, B. Gimeno, J. Capmany and L. Dong, "Array factor of a phased array antenna steered by a chirped fiber grating beamformer", *IEEE Photonics Technology Letters* **10**, 1153-1155(1998).
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45. John M. Ballato, Thomas W. Hawkins, Peter D. Dragic, Magnus Engholm, Michel J. F. Digonnet, and Liang Dong, "Material approaches to thermal management in advanced fiber lasers and amplifiers," SPIE Photonics West, **Keynote Presentation**, January 27 – February 1, 2023.

Other public presentations

1. Liang Dong, OSA Webinar on "Recent Developments and potential challenges in high power fiber lasers", October 5, 2017.
2. Liang Dong, OSA Webinar on "High power fiber lasers", February 10, 2021.

Featured articles

1. L. Dong, M.J. Cole, A.D. Ellis, M. Durkin, M. Ibsen, V. Gusmeroli and R.I. Laming, "40 Gb/s 1.55 μ m transmission over 109 km of non-dispersion shifted fiber with long continuously chirped fiber gratings," Optics and Photonics News, (January 1997).
2. L. Dong, B. Ortega, L. Reekie, J.P. de Sandro, D.O. Culverhouse, S.G. Farwell and R.I. Laming, "Novel high performance all-fiber add/drop optical multiplexer based on a selective fused coupler and a single fiber Bragg grating," Optics and Photonics News, (January 1998).
3. L. Dong, M. Toro and V. Rice, "Specialty fiber addresses limitations of fiber Bragg gratings," Laser Focus World, front cover photo, June, 63-66(2000).
4. "New optical fiber breaks effective mode diameter limit," Laser Focus World, (November 2005).
5. "Large area fiber target high power applications," Susan Curtis, optics.org. (May 2008).
6. "Suspended core fiber show high nonlinearity," Laser Focus World, (January, 2009).
7. "Fiber lasers look to large mode areas," Optics & Laser Europe, (April 2009).
8. "Material advantage and the power of light," Glimpse, Fall 2012
9. "Clemson University's COMSET builds on Nufern partnership," Laser Focus World, 2013
10. "Clemson University researcher making lasers more powerful," GSA Business, 2015

Granted Patents

1. "Chirped optical fiber gratings", GB9503555.6, WO96/26458, US6169829, NZ336940, AU4727596, AU710974, BR9607407, CA2213572, DE69623139D, EP0811175, GB2300930, JP11504123T, NZ301775, NZ301775, US6303041, AU734849, AU3689199, with J.L. Cruz, L. Reekie and R.I. Laming;
2. "Optical Waveguide Device", GB9508712.8, WO96/34304, EP0823062, US6160944, DE69602938D, DE69602938T, ES2132916T, JP11509330T, with J.L. Cruz and D.N. Payne.
3. "Optical Fiber and Optical Fiber Device", GB9703078.7, US08/810,128, US5881197, with L. Reekie and D.N. Payne.
4. "Optical coupler and/or multiplexer", GB9708045.1, GB9716970.0, WO9848305, US6278818, AU7064398, AU725596, DE69808111D, EP1012645, JP2001521645T, WO9848305, with R.I. Laming.
5. "Optical fiber and optical fiber grating", US6278818, US6009222, with D.N. Payne and L. Reekie.
6. "Optical fiber filters", GB9803275.8, WO99/41628, CA2321038, AU2535199, DE69903269D, EP1057056, JP2002503826T, US6718107, with B. Ortega and D.N. Payne.
7. "Optical Fiber and Optical Fiber Device", WO0002290, US6614975, AU4635399, CA2336335, EP1095432, with D.J. Richardson, N.G. Broderick, Offerhaus, R. Sammut.
8. "Distributed resonate ring fiber filter", US6192179, US6337763, US6429963, WO0043816, EP1181587, AU3582200, TW419600, CN1347511T, with G. Berkey.
9. "Asymmetric low dispersion Bragg grating filter, US 6278817, EP1218784, AU6208400, TW460721, WO0116633.
10. "Optical fiber filters", US6718107, with David Neil Payne and Beatrice Ortega Tamarit.
11. "Fiber Bragg grating with cladding mode suppression", US6351588, EP1240537, AU7079400, WO0122136, with Gang Qi, Marlene Marro, Vikram Bhatia, Marty Swan, Adam Collier and David Weidman.
12. "Dispersion compensating module and mode converter, coupler and dispersion compensating optical waveguide therein", US6640031, US6453102, AU3265301, WO0159496, with Gang Qi, and David L. Weidman.
13. "Optical fiber multiplexer", US7016573, US7327920, with Donald J. Harter.
14. "Single mode propagation in fibers and rods with leakage channels", US 7787729, with William S. Wong and Martin E. Fermann.
15. "Large core holey fibers", US7280730, US 8861913, US 8,285,099, with William S. Wong and Donald Harter.
16. "Photonic bandgap fibers", US7209619, US7418836, US 7792394 with Xiang Peng.
17. "Rare earth doped large effective area optical fibers for fiber lasers and amplifiers", US7450813/8542968/8213758, X. Peng.
18. "Ultra high numerical aperture optical fibers" US8467648/8705924/8023788/7496260, with X. Peng, and B.K. Thomas.
19. "Ultra small core fiber with dispersion tailoring" US882847/8165441 with B. Thoma and L. Fu
20. "Wide bandwidth, low loss photonic bandgap fibers" US 8285098, with B.K. Thomas, S. Suzuki and L. Fu
21. "Multi-clad optical fibers with corrugated boundary at pump cladding" US 8,213,077/8736955, with H. McKay
22. "Highly area-earth-doped optical fibers for fiber lasers and amplifiers" US 8498046, with M.E. Fermann, H. McKay, L. Fu and S. Suzuki
23. "Auto-clad multi-core optical fibers" with M.E. Fermann, L. Fu and H.A. McKay, US 8970947.
24. "High power parallel fiber arrays" with M.E. Fermann, I. Hartl, A. Marcinkevicius, US 0203884/9013786/8199398.
25. "Glass large-core optical fibers" with J. Li, H. McKay, L. Fu and A. Marcinkevicius, US 8995051/8159742.
26. "All glass leakage channel fibers and devices using them" US8849083, with Bryce Samson, Kanxian Wei.
27. "High power optical fibers", with K. Saitoh, US9146345 B1.
28. "Three-Level System Fiber Lasers Incorporating an All-Solid Photonic Bandgap Fiber" US 17/026,760 filed October 25th, 2019.

HONORS AND AWARDS

1. Technical Cooperation Scholarship, the British Council (1985).
2. Commendation for Excellence in Technical Communications, Laser Focus World (2000).
3. OSA fellow, 2014
4. SPIE fellow, 2017
5. IEEE senior member 2017
6. University Research, Scholarship, and Artistic Achievement award, May 2018
7. Dean's Distinguished Professor Award in the Department of Electrical and Computer Engineering, 4/16/2019 to 4/15/2022
8. IEEE fellow, 2019
9. SPIE Community Champion 2021

SPONSORED RESEARCH

1. "Large Core All-Solid Photonic Bandgap Fibers," IRAD, Northrop Grumman IT Inc. ChK#2058988, Principal Investigator, \$50,000 (2010-2011). Dong Share = 100%.
2. "Polarization-Maintaining Large-Core All-Solid Photonic Bandgap Fibers for Power Scaling of High-Power Fiber Lasers", MDA HQ0147-11-C-6010, Principal Investigator, \$791,826 (2011-2014). Dong Share = 70%.
3. "Advanced Optical Fibers for High Power Fiber Lasers," JTO-HEL MRI W911NF-10-1-0423, Principal Investigator, \$2,356,840 (2010-2018). Dong Share = 70%.
4. "DURIP: Acquisition of Fabrication Equipment for High Power Laser Research," Department of Defense, co-PI, \$150,000 (08/2011-07/2012). Dong Share = 50%.
5. "Novel Fiber Concepts for High Power Single Mode Fiber Lasers," JTO-HEL MRI W911NF-12-1-0332, Principal Investigator, \$2,460,000 (2012-2019). Dong Share = 70%.
6. "Advanced Optical Fiber Development for Fiber Lasers with Sub-GHz Linewidth," US Dept. of the Army, W911NF-14-1-0647, Principal Investigator, \$300,000 (2014-2015). Dong Share = 100%.
7. "Advanced Optical Fiber Development for Fiber Lasers with Sub-GHz Linewidth," US Dept. of the Army, W911NF-14-1-0629, Principal Investigator, \$108,000 (2014-2015). Dong Share = 100%.
8. "All-solid Photonic Bandgap Fibers for kW-level Narrow-Linewidth Single-mode CW Fiber Lasers," US Army, Principal Investigator, \$1,100,000 (2018-2021). Dong Share = 100%.
9. "Optimization of Tm-Doped Phosphosilicate Glass for High Power Fiber Lasers," US Air Force, Principal Investigator, \$100,000 (2016-2017). Dong Share = 100%.
10. "Thulium mode locked fiber lasers," IRAD, Raytheon. Principal Investigator, \$50,000(2015-2016). Dong Share = 100%.
11. "Power scaling of combinable fiber lasers to beyond 5kW," US Dept. of the Army, W911NF-17-1-0454, Principal Investigator, \$614,999 (2017-2019). Dong Share = 100%.
12. "Tm-doped Photonic Bandgap Fibers, Continuation of W911NF-12-1-0332," US Army, Principal Investigator, \$61,999 (2019-2020). Dong Share = 85%.
13. "A Study of Single-Frequency MOPA Based on Fiber Lasers for Starshot," Breakthrough Starshot, Principal Investigator, \$149,838 (2021-2022). Dong Share = 100%.
14. "A Unified Materials Approach to Mitigating Nonlinearities in HEL Optical Fibers," Joint Technology Office High Energy Laser Multidisciplinary Research Initiative (JTO HEL MRI) through the Office of Naval Research, 1-Sep-2017 to 31-Aug-2022; Co-PI, Award Total: \$1,660,891. Ballato PI; Dong Share = 10%.
15. "Hollow-core MWIR Optical Fibers." US Dept. of the Army, W911NF-19-1-0409, Principal Investigator, \$399,123 (2019-2024). Dong Share = 100%.
16. "Intrinsically SBS Suppressive Fiber Amplifiers for Future Directed Energy Weapons Systems," US Air Force, Principal Investigator, \$272,000 (2021-2024). Dong Share = 100%.
17. "Advanced Technologies for High Energy Laser Applications," US Army Space and Missile Defense Command (SMDC), Co-PI, Award Totals: Year 1 (2021-2022): \$4,991,570 (Dong Share = 10%). Year 2 (2022-2023): \$5,387,500 (Dong Share = 10%). Year 3 (2023-2024): \$4,033,823 (Dong Share = 13%). Year 4 (2024-2025): \$4,218,452 (Dong Share = 13%). Joe Watkins, PI.
18. "High power narrow-linewidth fiber lasers," Strategic Missile Defense Command, Principal Investigator, \$326,913 (2024). Dong Share = 70%.
19. "Understanding Nano-Engineered Optical Fibers for Power-Scaled Fiber Lasers," US Air Force, Principal Investigator, \$429,360 (2024-2027). Dong Share = 33%.
20. "Efficient High-Power Diffraction-Limited Fiber Lasers with Ultra-Low Quantum Defect," US Dept. of the Army, W911NF-25-1-0227, Principal Investigator, \$511,354 (2025-2027). Dong Share = 100%.

OTHER SPONSORED ACTIVITY

- "Development of High-Power Fiber Lasers, HIRAFS", UK DTI/Link project, co-investigator, (1995-1997).
- "Photosensitive Devices, PHOTOS", European Community project, co-investigator, (1995-1997).
- "Photonic Bandgap Fibers", UK EPSRC project, co-investigator (1997-2000).
- "Multi-port fiber Bragg grating devices for optical add/drop multiplexing", UK EPSRC-ROPA funding, co-investigator (1998-2000).

GRADUATE STUDENT ADVISING

Current students

Samuel Bingham
Jannatul Mawa Nijhum
Jackson Davis

Graduated students

Mark Mahilik, MSc, "A Study of a Monolithic Pulses Fiber Laser with High-peak and Average Power" May 2022

Turghun Matniyaz, PhD, "Power Scaling of Single-Mode High Power Er³⁺ and Yb³⁺ Fiber Lasers" May 2020

Thomas Wade Hawkins, PhD, "The Materials Science and Engineering of Advanced Yb-Doped Glasses and Fibers for High-Power Lasers" May 2020

Guancheng Gu, PhD, "Advanced Specialty Fiber Designs for High Power Fiber Lasers", August 2016, Clemson University

Christopher Dunn, MSc, "Tellurite Fiber for High Power Mid-Wave Infrared Supercontinuum Generation", August 2016, Clemson University

Wen-Fung Liu, PhD, "Optical Fiber Gratings and Their Applications as Acoustooptic Devices," (graduated in March 1998 from Southampton University).

Beatriz Ortega Tamarit, PhD, "Análisis, diseño, fabricación, medida, y aplicaciones, de nuevos dispositivos fotónicos basados en acoplo modal codireccional y contradireccional en fibras ópticas," (graduated in April 1999 from Universidad Politécnica de Valencia).

UNIVERSITY AND PUBLIC SERVICE

Committees

VPR Advisory Board, alternate, (2017-)

Search committee for the Samuel Bell Distinguished Professor in ECE (2012-2013)

COES Initiatives Working Group (2011)

Program committee for photonics MS/PhD programs (2010-)

Search committee for the PalmettoNet endowed chair in optoelectronics in ECE (2010-2011)

Search committee for the Sirrine endowed chair in fiber optics in MSE (2009-2015)

MSc/PhD Examination Committees,

Academic course committees, Applied Electromagnetics, (2010-)

Other Service

External examiners:

PhD defense of Mette Marie Johansen at Denmark Technical University Fotonik, Denmark, on 21. April 2017

Victor Distler, PhD candidate, department of Physics and Astronomy of the Friedrich Schiller University Jena, Germany, 2021

Christopher Aleshire, PhD candidate, department of Physics and Astronomy of the Friedrich Schiller University Jena, Germany, 2024

Robbie Mears, PhD candidate, department of Physics, Bath University, UK, 2025

Date of most recent resume update: December 2025.