

Exhibit C7

NKT Photonics Inc.'s Invalidity Claim Chart for U.S. Patent No. 7,433,116

For at least the following reasons, Defendant contends that Claims 1–4, 9, 12–14, 16, 19, 20, and 22–24 of U.S. Patent No. 7,433,116 (“the ’116 Patent”) are invalid pursuant to pre-AIA 35 U.S.C. § 103 in light of the combination of some or all of the following patents or publications:

- U.S. Patent Publication No. 2003/0012491, published on January 16, 2003 (“Shaw”) (NKTP0000037);
- U.S. Patent No. 6,212,310, issued on April 3, 2001 (“the ’310 Patent”) (NKTP000158);
- U.S. Patent No. 6,340,806, issued on January 22, 2002 (“the ’806 Patent”) (NKTP000206);
- “Raman Amplification in As-Se Fiber,” SPIE Vol. 4628, published in 2002 (“Thielen”) (NKTP000005);
- “1.3 μ m Cascaded Raman Amplifier in Germanosilicate Fibers,” OSA, published in 1994 (“Grubb”) (NKTP000001);
- U.S. Patent No. 5,323,404, issued on June 21, 1994 (“the ’404 Patent”) (NKTP000046);
- U.S. Patent No. 6,081,369, issued on June 27, 2000 (“the ’369 Patent”) (NKTP000125);
- U.S. Patent No. 6,239,903 B1, published on May 29, 2001 (“the ’903 Patent”) (NKTP000188);
- International Patent Application with Publication Number WO 01/65646 A2, published on September 7, 2001 (“Fidric”) (NKTP000026);
- U.S. Patent No. 5,696,778, published on December 9, 1997 (“the ’778 Patent”) (NKTP000056);
- U.S. Patent Publication No. 2002/0168161, published on November 14, 2002 (“Price”) (NKTP000009);
- U.S. Patent No. 6,163,636, published on December 19, 2000 (“the ’636 Patent”) (NKTP000149);
- U.S. Patent No. 6,337,462, issued on January 8, 2002 (“the ’462 Patent”) (NKTP000392);
- U.S. Patent No. 6,373,869, issued on April 16, 2002 (“the ’869 Patent”) (NKTP000417);
- U.S. Patent No. 6,236,779, issued on May 22, 2001 (“the ’779 Patent”) (NKTP000386);

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- U.S. Patent No. 5,048,034, issued on September 10, 1991 (“the ’034 Patent”) (NKTP000354);
- U.S. Patent Publication No. 2002/0023901 A1, published on February 28, 2002 (“Smart”) (NKTP000335);
- U.S. Patent No. 5,880,877, issued on March 9, 1999 (“the ’877 Patent”) (NKTP000363); and
- U.S. Patent Publication No. 2002/118709, published on August 29, 2002 (“Islam2002”) (NKTP000432).

A POSITA would have been motivated to use the laser sources and fibers described herein to create an infrared source at a variety of different wavelengths. As demonstrated in these references, Raman lasers were well known at the time of the filing of the patent application that led to the ’116 Patent, as was the concept of combining different wavelength sources using WDMs, beam combiners, dichroic mirrors and the like to wavelength shift laser light using the Raman effect. In addition, the concept of cascading fibers to achieve longer wavelength shifts was also well known, as demonstrated by these references. The references disclosed operate in roughly the same wavelength ranges. Thus, a POSITA would be motivated to use these disclosures to create longer-wavelength infrared light than was possible from traditional laser sources alone.

To the extent that any of these references by themselves do not anticipate the asserted claims of the ’116 Patent, the combination of two or more of these references would have been a natural extension of the results of the references and would have been an obvious combination to try to achieve longer wavelength shifts using a Raman effect.

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<i>Claim Term</i>	<i>References</i>
1. An infrared light source, comprising:	Shaw states that it is an infrared laser (light) source: “This invention describes a new approach for achieving high efficiency Raman glass fiber lasers and amplifiers in the infrared region.” (Shaw, p. 2, ¶ 20). The '310 Patent describes a system for creating light in the $>1\text{ }\mu\text{m}$ wavelength range, which would be an infrared light source. ('310 Patent, Col. 9:26–31). The '806 Patent describes a system for creating light in the $>1\text{ }\mu\text{m}$ wavelength range, which would be an infrared light source. ('806 Patent, Col. 18:2–5, 36–41). Thielen states that the system produces $1.56\text{ }\mu\text{m}$ light, which is in the infrared range. (Thielen, p. 74). Grubb states that the system produces $1.3\text{ }\mu\text{m}$ light, which is in the infrared range. (Grubb, p. PD3-2). The '404 Patent describes a light source that produces light in the $0.8\text{--}2.0\text{ }\mu\text{m}$ range, which is in the infrared. ('404 Patent, Col. 7:57–59). The '369 Patent describes an optical system that produces light from at least $0.9\text{--}2.1\text{ }\mu\text{m}$, which is in the infrared. ('369 Patent, Col. 6:42–65). Example 5 in the '903 Patent (Col. 7:62–67) states that “the $1430\text{--}1530\text{ nm}$ range” can be reached, and further “a broadband gain is expected for wavelengths in the $1430\text{--}1530\text{ nm}$ range.” Wavelengths in the range of $1430\text{--}1530\text{ nm}$ correspond to infrared light according to the common definition of the term in the field. The wavelength range of $1430\text{--}1530\text{ nm}$ is also disclosed in the embodiments of Fig. 9 ('903 Patent, Col. 9:9–12) and Fig. 12 ('903 Patent, Col. 10:65–67). Fidric states that “the gain spectrum 300 of the erbium amplifier extends from about 1530 nm to 1560 nm whereas the gain spectrum 302 of the Raman amplifier can be

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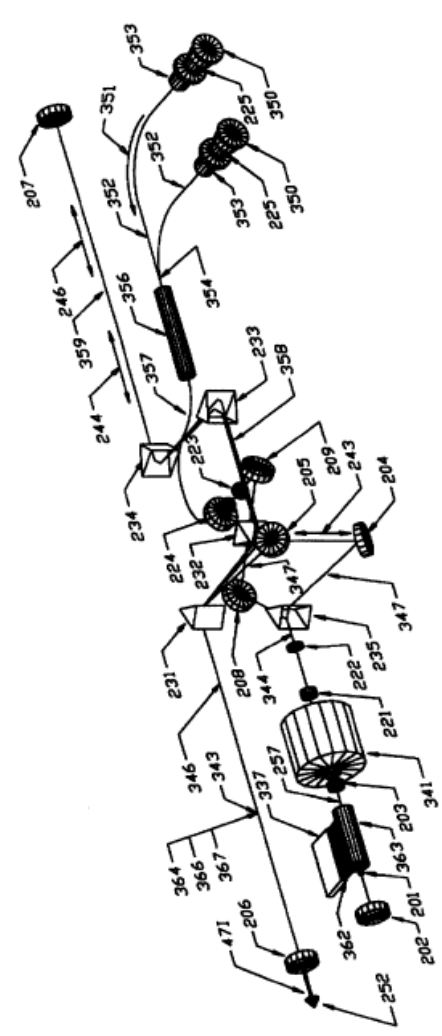
Claim Term	References
	adjusted to span from 1560 nm to 1580 nm.” (Fidric, p. 10, ll. 9–12). These wavelengths are well-known to belong to the infrared regime. The ’778 Patent states that “[a]pparatus performs a method of generating one output laser pulses in a range of 2 to 5 microns using an intracavity feature.” (Abstract). The ’778 Patent further states that “[f]or example, a Raman device 43 filled with deuterium will double-Raman shift the Cr:LiSAF tuning band 44 of 750 nm to 1000 nm to infrared wavelengths of from 1.36 microns to 2.49 microns.” (Fidric, Col. 12:43–46). The ’778 Patent further states that “injection seeding at two temporally closely spaced wavelengths (as described in respect to FIG. 41) is used to produce the beam 471 having pairs of output mid IR pulses.” (Fidric, Col. 33:27–30). Fig. 24 in the ’778 Patent shows one example of such a light source.  FIG 24 Price discloses “a continuously tunable source of optical soliton pulses operable over the wavelength range 1.06-1.33 μm and based on SSFS in holey fiber technology.”

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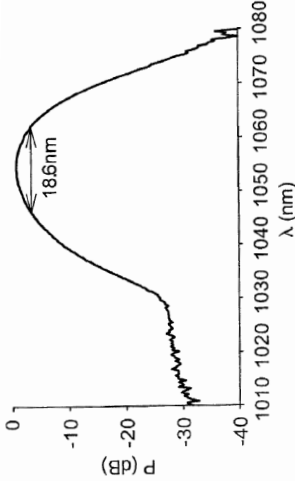
Claim Term	References
	(Price, p. 4, [0060]). This wavelength range falls within infrared light. Thus, Price discloses an infrared light source. Furthermore, Fig. 3(b) of Price shows the spectrum (power, P, against wavelength, λ) of the positively chirped pulses, which covers infrared light:  Fig. 3(b) The '636 Patent states in Example 1 that “[s]ignal wavelengths fall within the range of 1530-1570 nm.” ('636 Patent, Col. 4:19-20). The '636 Patent further states that “[i]n a preferred embodiment the system uses signal wavelengths in the range 1530-1570 nm, first order Raman pumping at 1430-1475 nm and second order pumping at about 1345 nm.” ('636 Patent, Abstract). Wavelengths in the range of 1530-1570 nm are well-known to fall within infrared light. The other wavelengths, 1430-1475 nm, and 1345 nm, are also examples of infrared light. Thus, an infrared light source is disclosed by the '636 Patent.

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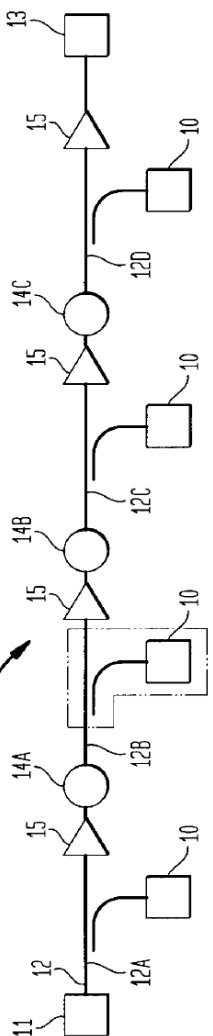
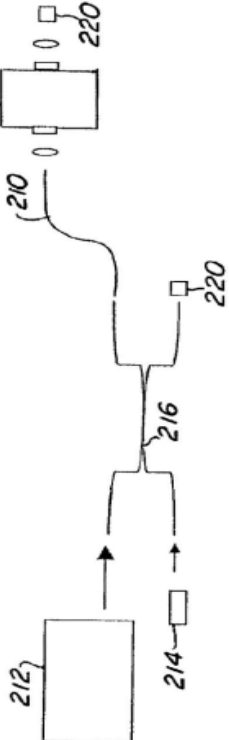
Claim Term	References
	FIG. 1  Islam2002 discloses an infrared light source—“[t]hus to achieve a 1310 nm signal wavelength four cascaded orders of Stokes shift would be employed, namely: 1117 nm to 1175 nm to 1240 nm to 1310 nm. Similarly, a fifth Stokes shift, based on the previous cascaded orders, would produce an output wavelength at 1480 nm.” (Islam2002, p. 6, ¶ 79).
one or more combiners coupled to	Shaw’s Example 1 states that it has a “2x2 coupler 216” that combines light from two different laser sources (212 and 214). (Shaw, p. 4, ¶ 41; Figure 8). A 2x2 coupler is a beam combiner that couples two different input sources. FIG. 8 

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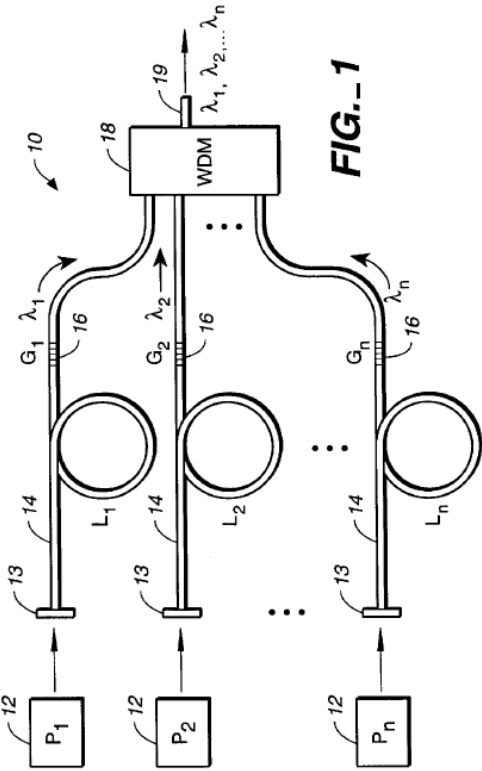
Claim Term	References
	The '310 Patent uses a wavelength division multiplexer (WDM) 18 to combine laser light from different laser sources ($L_1, L_2, \dots L_n$). "For example, laser L_1, may operate at a wavelength of 1080 nm, L_2 at 1085 nm, L_3 at 1190 nm, etc., and L_n at 1100 nm. The output from multiple fiber lasers 14 are combined through a wavelength division multiplexer (WDM) 18, such as a dichroic mirror or a nxn fused fiber coupler." ('310 Patent, Figure 1; Col. 9:9–13). The '310 Patent discloses another embodiment with a similar combiner configuration in Figure 3.  FIG. 1

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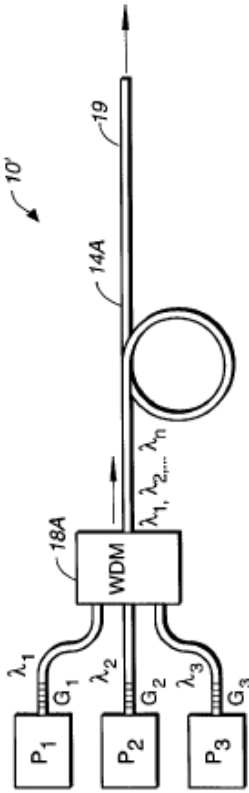
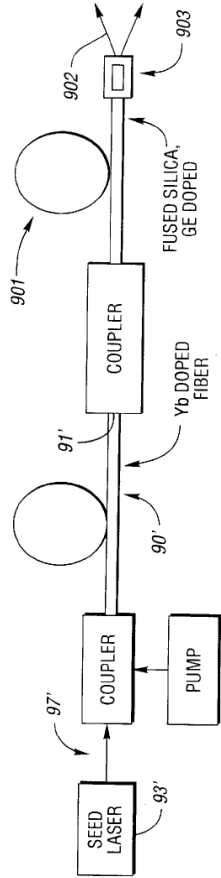
Claim Term	References
	 FIG. 3
	Figure 14 in the '806 Patent shows a coupler (combiner) that combines light from a seed laser 93' and a pump laser.  Fig. 14

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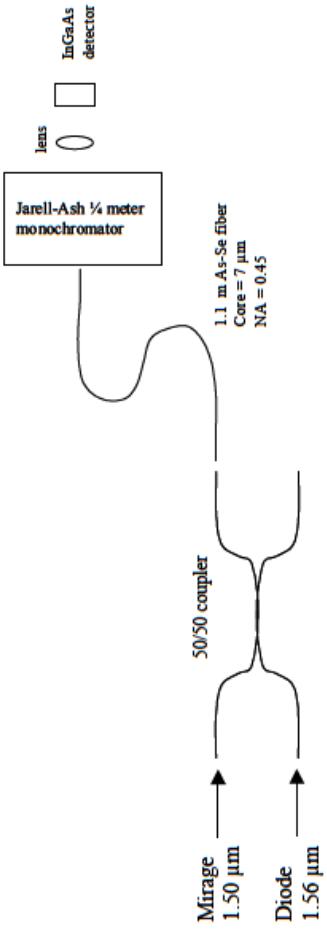
Claim Term	References
	Thielen states that it has a “50/50 silica fiber coupler” that combines light from two different laser sources (Mirage and Diode). (Thielen, p. 75; Figure 3). A 50/50 coupler is a beam combiner that couples two different input sources.  The diagram illustrates the experimental setup for measuring Raman amplification. At the bottom, two laser sources are shown: 'Mirage 1.50 μm' and 'Diode 1.56 μm'. Arrows from these sources point to a central '50/50 coupler'. From the coupler, a single line leads to a 'Jarell-Ash ¼ meter monochromator'. The output of the monochromator passes through a 'lens' and is then detected by an 'InGaAs detector'. Figure 3: Diagram of setup to measure Raman amplification As shown in Figure 1, Grubb uses a wavelength division multiplexer (WDM) to combine light from two different sources. (Grubb, p. PD3-4).

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	Figure 1 consists of two schematic diagrams, (a) and (b), illustrating optical fiber-based laser and amplifier configurations. Diagram (a) shows a third-order cascaded Raman laser. It features a pump input at 1060 nm, a signal input at 1.3 μm, and a trade-off output at 1240 nm. The diagram includes a series of fiber gratings and a WDM (Wavelength Division Multiplexer) component. A PD3-4 component is also shown. Diagram (b) shows a third-order intracavity-pumped cascaded 1.3 μm Raman amplifier. It features a pump input at 1064 nm, a signal input at 1.3 μm, and a signal output at 1.3 μm. The diagram includes a series of fiber gratings and a WDM component. The text '1310/1064' is also present near the WDM component in both diagrams.
	Figure 1: a) schematic of the third-order (1240 nm) cascaded Raman laser, b) third-order intracavity-pumped cascaded 1.3 μm Raman amplifier.
	The '404 Patent uses a wavelength division multiplexer (WDM) to couple light from two optical sources—"Signal radiation 41 is coupled into fiber 43 (e.g., by means of a conventional fusion splice between 41 and a conventional transmission fiber, not shown). Pump radiation 42 from pump radiation source 44 is also coupled into 43, e.g., by means of a conventional wavelength division multiplexer (WDM)." ('404 Patent, Col. 6:17-23; Figure 4).

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	FIG. 4 FIG. 3 In the '369 Patent, a dichroic beamsplitter 67 combines light from laser diode 61 and laser diode pump source 65 into rare-earth doped fiber 63. ('369 Patent, Col. 10:16-20; Figure 3).

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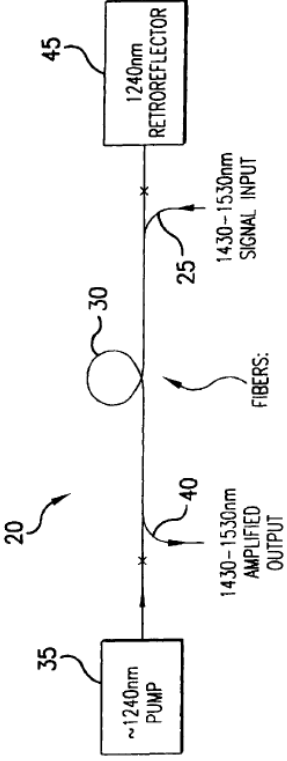
Claim Term	References
	The '903 Patent states in relation to the first embodiment (Fig. 9): "the input port and output port each comprises a WDM coupler which transmits at least at a wavelength between about 1240 nm and 1425 nm." ('903 Patent, Col. 10:16–19).  FIG. 9 The WDM2 in Figs. 10–11 of the '903 Patents combines different wavelength signals. The '903 Patent further states in relation to Fig. 12 that: "It is preferred that both the dividing means 230 and the combining means 260 are WDM couplers." ('903 Patent, Col. 11:49–51). Fidric discloses a wavelength division multiplexer (WDM), which is a type of combiner, on many occasions throughout the description. Such WDMs form part of a plurality of the embodiments disclosed in Fidric, for example in the embodiment of Figs. 1, 2, 4 (elements 12, 16, 18, 24), Fig. 6 (elements 12, 16, 24), Fig. 9 (elements 912, 916, 924), Fig. 10 (elements 1012, 1016, 1018), Fig. 11 (elements 1112, 1118, 1136, 1144), and Fig. 12 (elements 1212, 1218, 1236, 1244).

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	FIG. 1 FIG. 2

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	FIG. 4 FIG. 6

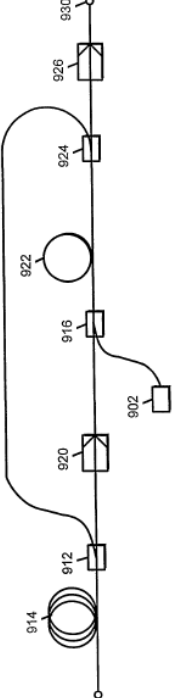
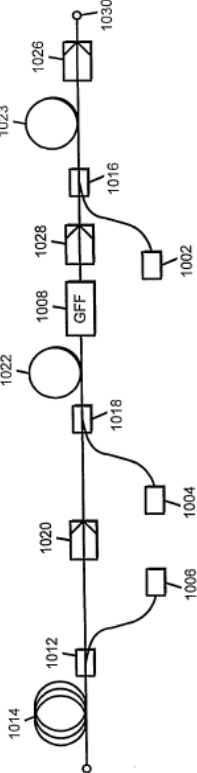
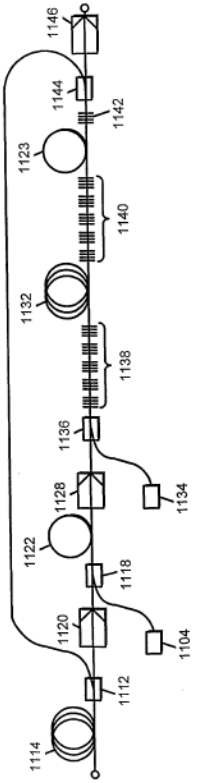
Claim Term	References
	 FIG. 9  FIG. 10  FIG. 11

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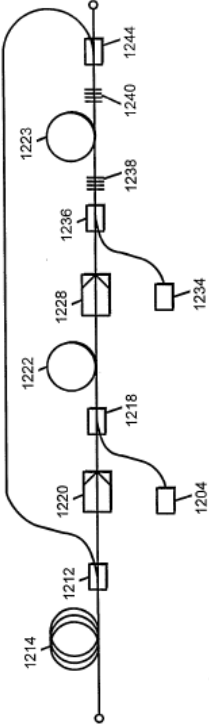
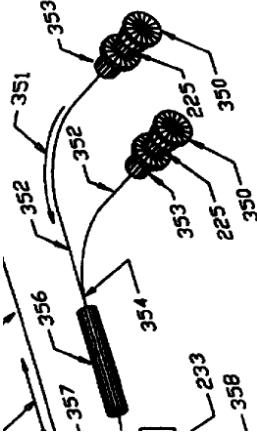
Claim Term	References
	 FIG. 12 The '778 Patent states that "[t]he fibers 352 are combined at a fiber splice 354 and fed into a Faraday isolator 356 which prevents the high power Q switched pump laser pulse 243 from damaging the diode lasers 350." ('778 Patent, Col. 28:10-13). Fig. 24 shows a combiner (element 354). 

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	Figures 1 and 4 of Price each show a dichroic mirror (element 54) for coupling light into a holey fiber (element 48). Fig. 4 The '636 Patent states in relation to the embodiment of Fig. 2 that “[t]he sources are typically semiconductor lasers and are coupled together, as by a coupler line segment 21. They are coupled into the fiber transmission line 12 as by a wavelength-division-multiplexer 22.” ('636 Patent, Col. 3:39–42).

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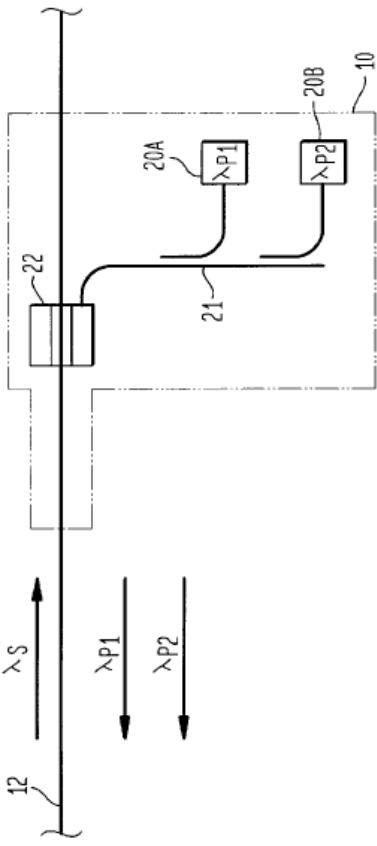
Claim Term	References
	FIG. 2  Furthermore, a wavelength-division-multiplexer is shown in Figs. 2, 7, and 9 of the '636 Patent (element 22), which is a type of combiner. Islam2002 discloses that “[t]he light source 26 is a pumped fiber laser coupled through a WDM port 28 to the optical resonator” (Islam2002, p. 5, ¶ 72) and “[t]he optical signal to be amplified, injected through WDM coupler 42.” (Islam2002, p. 5, ¶ 73). The two optical signals are combined in WDM coupler 42. A WDM (wavelength division multiplexer) is a type of combiner.

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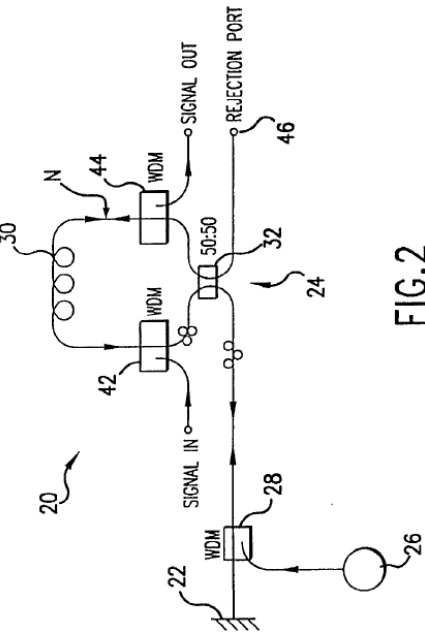
Claim Term	References
at least a first pump laser operable to generate a first pump signal and	 FIG. 2
at least a first pump laser operable to generate a first pump signal and	Shaw's Example 1 has a "pump" laser 212 at 1.5 μm from a Continuum Mirage OPO laser (8 W of power with 5 ns pulses). "The device was pumped with Continuum Mirage OPO 212 at 1.5 μm with about 8 W of peak power in a 5 ns pulse." (Shaw, p. 4, ¶ 41). This "pump" laser is a "first pump laser" that generates a "first pump signal." The '310 Patent discloses laser L_1 (reference 14 in Figure 1), which is a fiber laser pumped by pump source P_1 (reference 12 in Figure 1). ('310 Patent, Fig. 1; Col. 7:57–61, Col. 8:24–30). Laser L_1 generates a laser signal λ_1. ('310 Patent, Col. 9:9–13). In Figure 3, the '310 Patent dispenses with the fiber lasers ($L_1...L_n$) and uses pumping sources $P_1...P_n$ with wavelengths $\lambda_1... \lambda_n$. ('310 Patent, Col. 11:52–61). Figure 14 in the '806 Patent shows a first pump laser (seed laser 93') that generates a first pump signal (seed laser output wavelength 97') ('806 Patent, Col. 18:2–4). Thielen has a "pump" laser at 1.5 μm from a Continuum Mirage OPO laser (8 W of power with 5 ns pulses and 10 Hz). "A Continuum Mirage OPO operating at a wavelength of 1.50 μm was used as a pump source." (Thielen, p. 75). This "pump" laser is a "first pump laser" that generates a "first pump signal."

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	Grubb has a 1064 nm “pump” laser that generates a first pump signal. (Grubb, p. PD3-4; Figure 1). The '404 Patent has a pump source 44 (first pump laser) that generates pump radiation 42 (first pump signal) at, for example, 1.064 μm. ('404 Patent, Col. 1:6-68, 6:16-28; Figure 4). The '369 Patent has a pump source 65 (first pump laser) that generates a pump signal with a wavelength of λ_p (first pump signal). ('369 Patent, Col. 10:16-20). The '903 Patent states in relation to Fig. 9 that: “The optical fiber 30 is pumped by a pumping light generated by a pumping laser 35 operated at a wavelength of about 1240 nm.” ('903 Patent, Col. 9:17-19). Pumping laser 35 is a first pump laser operable to generate a first pump signal. Furthermore, Figs. 10-11 of the '903 Patent shows a first pump laser 80 (labelled “~1240nm PUMP”) and 120 (labelled “~1117nm PUMP”). FIG.10

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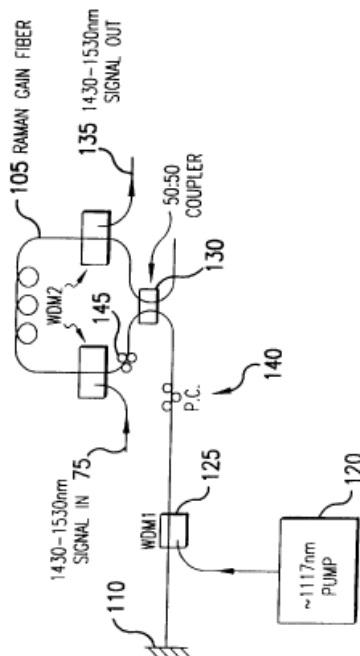
Claim Term	References
	 FIG. 11 Fidric has a first pump laser (P₁) that produces a first pump signal (λ_1)—"[a] third WDM 18 has input ports 18a, 18b through which are fed respective ones of pump signals P₁, P₂ having respective wavelengths λ_1, λ_2." (Fidric, p. 8, ll. 3-4). The '778 Patent states that "injection seeding at two temporally closely spaced wavelengths (as described in respect to FIG. 41) is used to produce the beam 471 having pairs of output mid IR pulses." ('778 Patent, Col. 33:27-30). The '778 Patent further states that "Step 428. Use two separate seed diodes 350. The wavelengths of the laser diodes 350 are closely spaced" ('778 Patent, Col. 33:36-37). The first seed diode is the first pump laser. Price states in relation to Fig. 1 that "[t]he optical source 12 is a mode-locked laser operable to generate ultrashort pulses at a wavelength of 1.06 μm with a positive linear chirp." (Price, p. 4, [0061]). It is noted that the optical source 12 also forms part of the embodiment of Fig. 4. The mode-locked laser 12 constitutes a first pump laser operable to generate a first pump signal.

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	Fig. 1 FIG. 7
All of the embodiments shown in Figs. 2, 7, and 9 of the '636 Patent show a first pump laser operable to generate a first pump signal (e.g., element 20A).	

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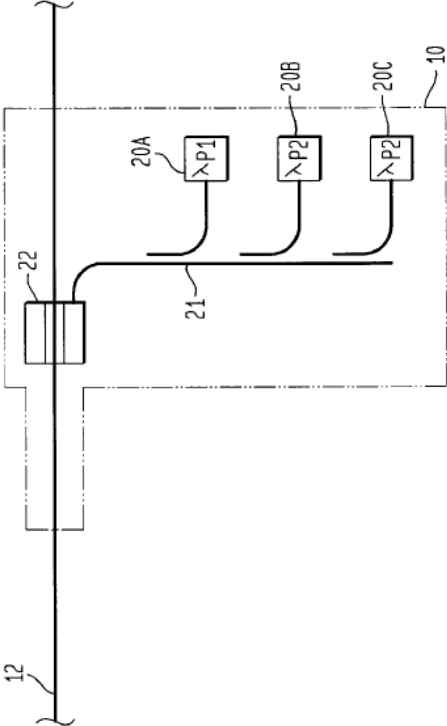
Claim Term	References
	FIG. 9  Islam2002 discloses that “[t]he light source 26 is a pumped fiber laser.” (Islam2002, p. 5, ¶ 72). “The wavelength of the optical energy from light source 26 will, of course, be chosen to match the desired application.” (Islam2002, p. 5, ¶ 73).
a second pump laser operable to generate a second pump signal,	Shaw’s Example 1 has a “signal” laser diode 214 at 1.56 μm. “The signal source 214 was a 1.56 μm diode laser that was mixed with the pump laser using a 2x2 coupler 216.” (Shaw, p. 4, ¶ 41). This “signal” laser would be the “second pump laser” that generates a “second pump signal” at a different wavelength. The ’310 Patent discloses laser L₂ (reference 14 in Figure 1), which is a fiber laser pumped by pump source P₂ (reference 12 in Figure 1). (’310 Patent, Fig. 1; Col. 7:57–61, Col. 8:24–30). Laser L₂ generates a laser signal λ₂. (’310 Patent, Col. 9:9–13). In Figure 3, the ’310 Patent dispenses with the fiber lasers (L₁...L_n) and uses pumping sources P₁...P_n with wavelengths λ₁...λ_n. (’310 Patent, Col. 11:52–61).

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<i>Claim Term</i>	<i>References</i>
	Figure 14 in the '806 Patent shows a second pump laser ("pump" in Fig. 14) that generates a second pump signal. The '806 Patent provides an example where the "pump" is a high-power laser diode array at 980 nm, while the seed laser 93' is at 1.064 microns. ('806 Patent, Col. 18:36–41). Thielen used a "signal" laser diode at 1.56 μm. "The seed signal to be amplified, a low power 1.56 μm laser diode, was coupled along with the pump source into a 50/50 silica fiber coupler." (Thielen, p. 75). This "signal" laser would be the "second pump laser" that generates a "second pump signal" at a different wavelength. Grubb has a 1.3 μm "signal" laser that generates a second pump signal. (Grubb, p. PD3-4; Figure 1). The '404 Patent has a laser source (second pump laser) that produces signal radiation 41 (second pump signal) at, for example, 1.310 μm. ('404 Patent, Col. 1:6–68, 6:16–28; Figure 4). The '369 Patent has a laser diode 61 (second pump laser) that generates a signal with a wavelength of λ_s (second pump signal). ('369 Patent, Col. 10:16–20). The '903 Patent states in relation to Fig. 9 that: "an optical signal having a wavelength between 1430 nm and 1530 nm is input from an input port 25 to an optical fiber 30." Furthermore, Figs. 10–11 of the '903 Patent shows a second pump laser operable to generate a second pump signal (labelled "1430–1530nm SIGNAL IN" in both figures). The two different signals are combined in WDM2 as seen in Figs. 10–11 of the '903 Patent. Fidric has a second pump laser (P_2) that produces a second pump signal (λ_2)—"a] third WDM 18 has input ports 18a, 18b through which are fed respective ones of pump signals P_1, P_2 having respective wavelengths λ_1, λ_2." (Fidric, p. 8, ll. 3–4).

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	The '778 Patent states that "injection seeding at two temporally closely spaced wavelengths (as described in respect to FIG. 41) is used to produce the beam 471 having pairs of output mid IR pulses." ('778 Patent, Col. 33:27–30). The '778 Patent further states that "Step 428. Use two separate seed diodes 350. The wavelengths of the laser diodes 350 are closely spaced" ('778 Patent, Col. 33:36–37). The second seed diode is the second pump laser. Price states in relation to Fig. 4 that "[t]he pump laser in this instance is a diode-based master oscillator power amplifier (MOPA) operable to generate pump radiation 49 at a wavelength of 966 nm" (Price, p. 5, [0070]). The diode-based MOPA constitutes a second pump laser operable to generate a second pump signal. Fig. 4 All of the embodiments shown in Figs. 2, 7, and 9 of the '636 Patent show a second pump laser operable to generate a second pump signal (e.g., element 20B). Islam2002 discloses that "[t]he optical signal to be amplified, injected through WDM coupler 42, may be at a wavelength of 1300 nm to 1310 nm." (Islam2002, p. 5, ¶ 73).

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Claim Term	References
the one or more combiners operable to combine the first pump signal and the second pump signal into a first optical signal,	Shaw's Example 1 uses coupler 216 to mix the pump laser signal ("first pump signal") with the signal laser signal ("the second pump signal"). (Shaw, p. 4, ¶ 41; Figure 8). As shown in Figure 8, the coupler combines these two signals and sends them to a 1-m section of As-Se fiber 210. FIG. 8 In the '310 Patent, WDM 18 combines the laser signals from lasers $L_1, L_2, \dots L_n$ to create a multi-wavelength output on fiber 19. "System may be combined with additional such systems with their outputs multiplexed together to form a single high power light output. The multiple wavelength outputs are combined, producing a high power multi-wavelength output on WDM coupled output monomode fiber 19." ('310 Patent, Fig. 1; Col. 9:9–13, 18–22). "In FIG. 3, in scaled power system 10', pump sources P_1, P_2 and P_3 have respective output gratings G_1, G_2 and G_3 that provide for respective wavelength outputs λ_1, λ_2 and λ_3, that are combined via WDM device 18A. The output of device 18A is provided to amplifier 14A which has an active dopant core for amplifying the

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	wavelength-combined pump source light providing an output on fiber 19 of high power.” (’310 Patent, Col. 11:58–65). The coupler in Figure 14 in the ’806 Patent combines the seed laser light (97’) with the pump laser light, i.e., combines first pump signal and second pump signal. Fig. 14 The 50/50 coupler mixes the pump laser signal (“first pump signal”) with the signal laser signal (“the second pump signal”). (Thielen, p. 75; Figure 3). “The seed signal to be amplified, a low power 1.56 μm laser diode, was coupled along with the pump source into a 50/50 silica fiber coupler.” (Thielen, p. 75). As shown in Figure 3, the coupler combines these two signals and sends them to a 1.1-m section of As-Se fiber.

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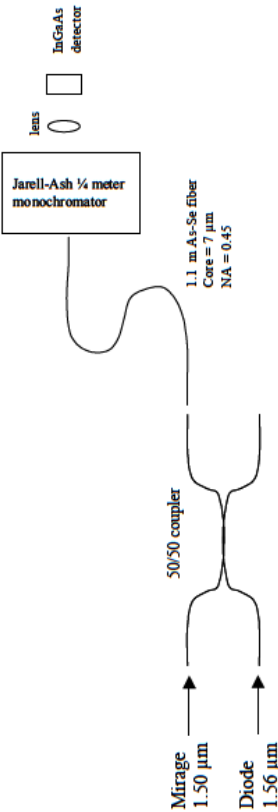
Claim Term	References
	 The diagram illustrates the experimental setup for measuring Raman amplification. Two laser sources, a 'Mirage 1.50 μm' and a 'Diode 1.56 μm', are shown with arrows pointing towards a '50/50 coupler'. The output of the coupler is a single line that enters an '1.1 m As-Se Fiber' with 'Core = 7 μm' and 'NA = 0.45'. The fiber is represented by a wavy line. After exiting the fiber, the signal passes through a 'Jarell-Ash ¼ meter monochromator' (a rectangular box), then through a 'lens' (a circle), and finally reaches an 'InGaAs detector' (a square). Figure 3: Diagram of setup to measure Raman amplification Grubb uses a wavelength division multiplexer (WDM) to combine the 1.3 μm and 1064 nm laser signals. (Grubb, p. PD3-4; Figure 1).

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	Figure 1 consists of two schematic diagrams, (a) and (b), illustrating optical fiber-based Raman amplification systems. Diagram (a) shows a third-order cascaded Raman laser. It features a pump input at 1060 nm, a signal input at 1.3 μm, and a 1240 nm HR (high reflector). The system includes a PD3-4 component and a 1240 nm output coupler. Wavelength markers at 1117 nm and 1175 nm are shown. Diagram (b) shows a third-order intracavity-pumped cascaded 1.3 μm Raman amplifier. It includes a 1.3 μm signal input, a 1064 nm pump input, and a 1.3 μm signal output. The system contains two Fiber Bragg gratings and a WDM (Wavelength Division Multiplexing) component. Wavelength markers at 1310 nm and 1064 nm are indicated.

Figure 1: a) schematic of the third-order (1240 nm) cascaded Raman laser, b) third-order intracavity-pumped cascaded 1.3 μm Raman amplifier.

The '404 Patent uses a WDM to combine pump radiation 41 (first pump signal) in fiber 43 with signal radiation 41 (second pump signal) to create a combined optical signal in fiber 43. ('404 Patent, Col. 6:16-28; Figure 4).

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	FIG. 4 In the '369 Patent, a dichroic beamsplitter 67 (combiner) combines the light from laser diode pump source 65 (λ_p—the first pump signal) and laser diode 61 (λ_s—the second pump signal) and into rare-earth doped fiber 63. ('369 Patent, Col. 10:16–20; Figure 3).

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	FIG. 3 Figs. 10–11 of the '903 Patent shows one or more combiners (labelled “WDM1” and “WDM2”) to combine the first pump signal and the second pump signal into a first optical signal. In particular, the 1240-nm pump signal is combined with the 1430–1530nm signal in WDM2. Furthermore, the input port 25 of Fig. 9 of the '903 Patent combines the first pump signal and the second pump signal into a first optical signal, because the 1240-nm pump signal is reflected from retro-reflector 45 (Fig. 9). The '903 Patent states that “The input and output ports are preferably WDM couplers” ('903 Patent, Col. 9:46–47). Fidric has a beam combiner (WDM)—“[a] third WDM 18 has input ports 18a, 18b through which are fed respective ones of pump signals P₁, P₂ having respective

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	wavelengths λ_1, λ_2. An output port 18c of WDM 18 is coupled to a second input port 16c of WDM 16.” (Fidric, p. 8, ll. 3–5). A WDM (wavelength division multiplexer) is a type of combiner. Furthermore, Figs. 1–2 of Fidric show a combiner (element 18) operable to combine the first pump signal (λ_1) and the second pump signal (λ_2) into a first optical signal. The ’778 Patent states that “Step 429. Combine the diode laser beams 351 at either a beam splitter or the fiber splice 354 before entering the pump cavity 330.” (’778 Patent, Col. 33:40–42). Price states that “[a] dichroic mirror 54 is provided for coupling light into the holey fiber 48. The pump radiation 49 is transmitted through the dichroic mirror 54, and focused into the holey fiber 48 by a lens 56.” (Price, p. 5, [0071]). Price further states that “[t]he ultrashort optical pulses 43 are generated by the optical source 12, and are coupled into the holey fiber 48 of the amplifier 14 together with the pump radiation 49 generated by the pump laser 16.” (Price, p. 6, [0086]). Price further states that “the pump radiation 49 and the pulses 43 counterpropagate in the holey fiber 48.” (Price, p. 8, [0106]). Thus, the dichroic mirror constitutes a combiner operable to combine the first pump signal and the second pump signal into a first optical signal. The wavelength-division-multiplexer 22 in the ’636 Patent is operable to combine the first pump signal and the second pump signal into a first optical signal. <i>See</i> Figs. 2 and 9. Islam2002 discloses that the two signals are combined in WDM coupler 42 (cf. FIG. 2). “[T]he two WDM couplers 42 and 44 can be designed for any desired signal wavelengths (not necessarily between 1300 nm and 1310 nm).” (Islam2002, p. 5, ¶ 73).
the first pump signal comprising at least a first wavelength and	In Shaw’s Example 1, the first pump signal has a wavelength of 1.5 μm . (Shaw, p. 4, ¶ 41).

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	The '310 Patent states that the various wavelengths of lasers L_1, L_2, ... L_n are different and uses the examples of $\lambda_1 = 1080$ nm, $\lambda_2 = 1085$ nm, $\lambda_3 = 1190$ nm. ('310 Patent, Col. 9:9–13). The '310 Patent also provides an example with $\lambda_1 = 980$ nm and $\lambda_2 = 1480$ nm. ('310 Patent, Col. 9:26–31). The '806 Patent provides an example where the first wavelength is 1.064 μm. ('806 Patent, Col. 18:36–41). The first pump signal in Thielen has a wavelength of 1.5 μm. (Thielen, p. 75). The first pump signal in Grubb has a wavelength of 1064 nm. (Grubb, p. PD3-4; Figure 1). The pump radiation 42 (first pump signal) in the '404 Patent can be at a wavelength of 1.064 μm. ('404 Patent, Col. 6:25–26). The light from pump source 65 (first pump signal) has a wavelength of λ_p. ('369 Patent, Col. 10:16–20). The '903 Patent states in relation to Fig. 9 that “pumping laser 35 is operated at a wavelength of about 1240 nm” ('903 Patent, Col. 9:18–19). This first pump signal is at a first wavelength. Fidric states that “[i]n operation, pump signals P_1 and P_2 having respective wavelengths λ_1 and λ_2 and pump powers pump the Raman amplifier 14” (Fidric, p. 8, ll. 10–11). Fidric further states that “two pump wavelengths are used to pump the multiple stage amplifier so as to provide a desired pumping of both stages.” (Fidric, p. 4, ll. 11–12). Fidric further states that “the pump source may be provided from two high-power laser diodes, each of which provides a signal having different output wavelengths in the band of 1420 nm to 1520 nm.” (Fidric, p. 9, ll. 32–34). Fidric further states that “[i]n another embodiment, two pump signals having wavelengths of

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	1465 nm and 1485 nm, respectively, are used to pump the Raman amplifier stage” (Fidric, p. 4, ll. 7–8). The ’778 Patent states that “[t]he wavelengths of the laser diodes 350 are closely spaced.” (’778 Patent, Col. 33:36–37). The ’778 Patent further states that “[a] diode laser injection seeder 71 contains one or more single mode diode lasers 72 (FIG. 15a) with a typical emission bandwidth of about 0.0004 nm and typical output power of a few milliwatts continuous wave.” (’778 Patent, Col. 13:51–55). Furthermore, Fig. 15a shows an embodiment with two pump lasers (elements 72): FIG. 15a Price states that optical source 12 is “a mode-locked laser operable to generate ultrashort pulses at a wavelength of 1.06 μm.” (Price, p. 4, [0061]). The ’636 Patent states in Example 2 that “the first-order pump has wavelengths ranging from 1430-1475 nm generated by sets of polarization-multiplexed diodes”

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	(’636 Patent, Col. 5:19–20), which constitutes a first pump signal comprising at least a first wavelength. Additionally, the embodiment shown in Fig. 9 of the ’636 Patent shows three pump lasers with different wavelengths, i.e., different pump signals. The ’636 Patent states that “the center wavelengths of the first, second-and third order pumps are approximately $\lambda_{p1}=1450$, $\lambda_{p2}=1360$ and $\lambda_3=1290$ nm.” (’636 Patent, Col. 5:44–46). Islam2002 discloses that “[b]y way of example, in an embodiment designed for 1.3 μm telecommunication applications, the light source 26 provides light at a wavelength of 1117 nm.” (Islam2002, p. 5, ¶ 73).
the second pump signal comprising at least a second wavelength,	In Shaw’s Example 1, the second pump signal has a wavelength of 1.56 μm. (Shaw, p. 4, ¶ 41). The ’310 Patent states that the various wavelengths of lasers L_1, L_2, ... L_n are different and uses the examples of $\lambda_1 = 1080$ nm, $\lambda_2 = 1085$ nm, $\lambda_3 = 1190$ nm. (’310 Patent, Col. 9:9–13). The ’310 Patent also provides an example with $\lambda_1 = 980$ nm and $\lambda_2 = 1480$ nm. (’310 Patent, Col. 9:26–31). The ’806 Patent provides an example where the second wavelength is 980 nm. (’806 Patent, Col. 18:36–41). The second pump signal in Thielen has a wavelength of 1.56 μm. (Thielen, p. 75). The second pump signal in Grubb has a wavelength of 1.3 μm. (Grubb, p. PD3-4; Figure 1). The signal radiation 41 (second pump signal) in the ’404 Patent can be at a wavelength of 1.310 μm. (’404 Patent, Col. 6:28). The light from laser diode 61 (second pump signal) has a wavelength of λ_s. (’369 Patent, Col. 10:16–20).

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<i>Claim Term</i>	<i>References</i>
	The '903 Patent states in relation to Fig. 9 that "an optical signal having a wavelength between 1430 nm and 1530 nm is input from an input port 25" ('903 Patent, Col. 9:15–16). This second pump signal is at a second wavelength. Fidric states that "[i]n operation, pump signals P₁ and P₂ having respective wavelengths λ_1 and λ_2 and pump powers pump the Raman amplifier 14" (Fidric, p. 8, ll. 10–11). Fidric further states that "two pump wavelengths are used to pump the multiple stage amplifier so as to provide a desired pumping of both stages." (Fidric, p. 4, ll. 11–12). Fidric further states that "the pump source may be provided from two high-power laser diodes, each of which provides a signal having different output wavelengths in the band of 1420 nm to 1520 nm." (Fidric, p. 9, ll. 32–34). Fidric further states that "[i]n another embodiment, two pump signals having wavelengths of 1465 nm and 1485 nm, respectively, are used to pump the Raman amplifier stage" (Fidric, p. 4, ll. 7–8). The '778 Patent states that "[t]he wavelengths of the laser diodes 350 are closely spaced." ('778 Patent, Col. 33:36–37). The '778 Patent further states that "[a] diode laser injection seeder 71 contains one or more single mode diode lasers 72 (FIG. 15a) with a typical emission bandwidth of about 0.0004 nm and typical output power of a few milliwatts continuous wave." ('778 Patent, Col. 13:51–55). Furthermore, Fig. 15a shows an embodiment with two pump lasers (elements 72):

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	FIG. 15a Price states that pump laser 16 is “operable to generate pump radiation 49 at a wavelength of 966 nm.” (Price, p. 5, [0070]). The ’636 Patent states in Example 2 that “[t]he second-order pump at approximately 1345 nm with an output power of 400 mW” (’636 Patent, Col. 5:22–24), which constitutes a second pump signal comprising at least a second wavelength. Additionally, the embodiment shown in Fig. 9 of the ’636 Patent shows three pump lasers with different wavelengths, i.e., different pump signals. The ’636 Patent states that “the center wavelengths of the first, second-and third order pumps are approximately $\lambda_{p1}=1450$, $\lambda_{p2}=1360$ and $\lambda_{p3}=1290$ nm.” (’636 Patent, Col. 5:44–46). Islam2002 discloses that “[t]he optical signal to be amplified, injected through WDM coupler 42, may be at a wavelength of 1300 nm to 1310 nm.” (Islam2002, p. 5, ¶ 73).

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<i>Claim Term</i>	<i>References</i>
wherein the first wavelength of the first pump signal is substantially different than the second wavelength of the second pump signal; and	In Shaw's Example 1, the first wavelength is different than the second wavelength (1.5 μm vs. 1.56 μm). While this term is asserted to be indefinite, the two wavelengths are measurably different from one another. In the '310 Patent, the first wavelength is different than the second wavelength (e.g., 1080 nm vs. 1190 nm or 980 nm vs. 1190 nm). While this term is asserted to be indefinite, the two wavelengths are measurably different from one another. While this term is asserted to be indefinite, the examples in the '806 Patent are different from one another and the '806 Patent specifically states that they are different. The first wavelength in Thielen is different than the second wavelength (1.5 μm vs. 1.56 μm). While this term is asserted to be indefinite, the two wavelengths are measurably different from one another. The first wavelength in Grubb is different than the second wavelength (1.064 nm vs. 1.3 μm). While this term is asserted to be indefinite, the two wavelengths are measurably different from one another. The first and second pump signals in the '404 Patent are at different wavelengths—1.064 μm and 1.310 μm. ('404 Patent, Col. 6:25–28). While this term is asserted to be indefinite, the two wavelengths are measurably different from one another. The first and second pump signals in the '369 Patent are at different wavelengths—λ_p and λ_s. ('369 Patent, Col. 10:16–20). The '369 Patent states that the two wavelengths are chosen so that the pump wavelength matches the absorption wavelength band in the fiber, which is different than the signal wavelength. ('369 Patent, Col. 6:42–65). While this term is asserted to be indefinite, the two wavelengths are different from one another.

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	While this term is asserted to be indefinite, a wavelength of 1240 nm is substantially different than a wavelength between 1430 nm and 1530 nm in the '903 Patent. Fidric states that “[i]n another embodiment, two pump signals having wavelengths of 1465 nm and 1485 nm, respectively, are used to pump the Raman amplifier stage” (Fidric, p. 4, ll. 7–8). While Defendant contends that this limitation is indefinite, a wavelength of 1465 nm is substantially different than 1485 nm. While Defendant contends that this term is indefinite, the '778 Patent states that the wavelengths are “closely spaced,” which implies that they are measurably distinct from each other. The '778 Patent further states that “the wavelength of the seeder light 73C from the diode laser injection seeder 71C (FIG. 18) is changed, resulting in the two output pulses 47C-1 and 47C-2 being at different selected wavelengths.” ('778 Patent, Col. 21:66–22:2). While this term is asserted to be indefinite, the two wavelengths in Price (1.06 μm and 966 nm) are measurably different from one another. While Defendant contends that this limitation is indefinite, the first wavelength of the first pump signal in the '636 Patent is substantially different than the second wavelength of the second pump signal. As an example, 1450 nm is substantially different than 1360 nm. Similarly, 1430–1475 nm is also substantially different than 1345 nm. While this term is asserted to be indefinite, the two wavelengths in Islam2002 are measurably different from one another. A wavelength of 1117 nm is substantially different than a wavelength of 1300 nm to 1310 nm.
a wavelength shifter coupled to the one or more combiners, the wavelength shifter comprising	In Shaw's Example 1, the As-Se fiber 210 (the “wavelength shifter”) is coupled to the 2x2 coupler 216. (Shaw, p. 4, ¶ 41).

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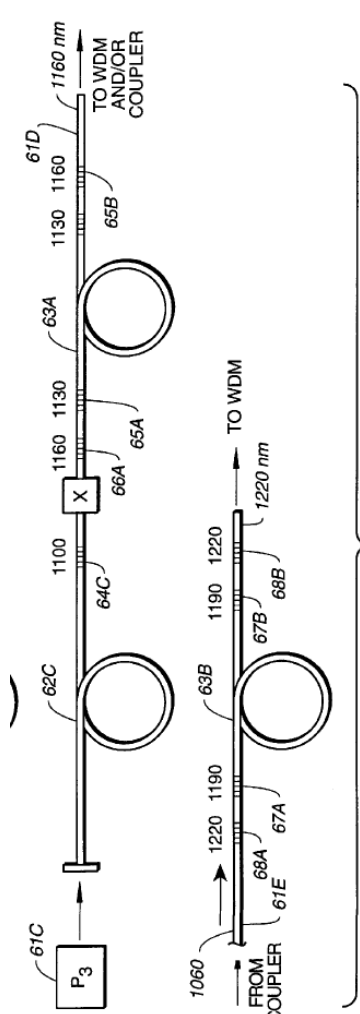
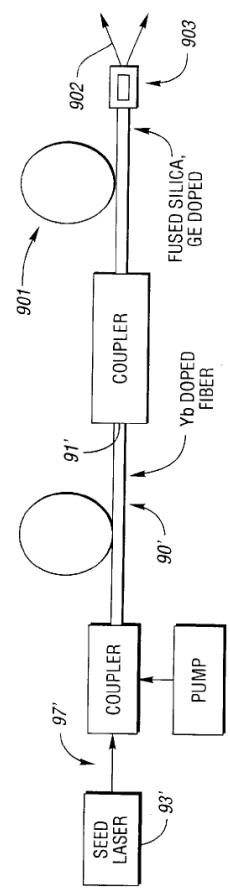
Claim Term	References
	The embodiment in Figure 22 in the '310 Patent describes a multi-staged wavelength shifter. ('310 Patent, Figure 22; Col. 21:35-42, Col. 22:30-36).  FIG. 22 The pump source P₃ and fiber laser 62C in Figure 22 could readily be replaced with the pumping sources/fiber lasers shown in Figures 1 and 3 to provide more power for the Raman fiber lasers 63A and 63B. In Figure 14, the '806 Patent couples the combined seed and pump laser pulses into a Yb-doped fiber amplifier 90', which is used to shift the wavelength of the seed laser pulse from 1.064 μm to 1.120 μm. ('806 Patent, Col. 17:65-18:5).  Fig. 14

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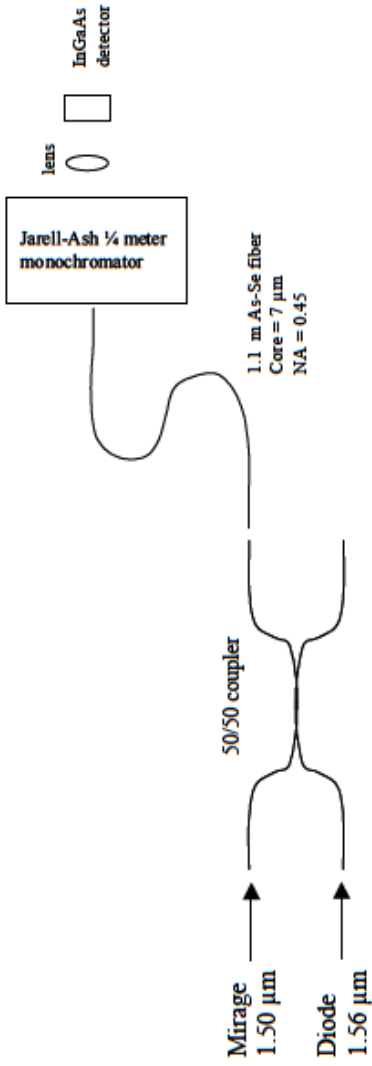
Claim Term	References
	The As-Se fiber in Thielen (the “wavelength shifter”) is coupled to the 50/50 coupler. “The seed signal to be amplified, a low power 1.56 μm laser diode, was coupled along with the pump source into a 50/50 silica fiber coupler. One of the output ports was butt-coupled to the As-Se fiber.” (Thielen, p. 75; Figure 3).  The diagram illustrates the experimental setup for measuring Raman amplification. At the top, a 'Jarell-Ash ¼ meter monochromator' is connected via a fiber to a '50/50 coupler'. The coupler has two input ports: 'Mirage 1.50 μm' and 'Diode 1.56 μm'. The coupler has two output ports: one leading to a '1.1 m As-Se fiber' with specifications 'Core = 7 μm' and 'NA = 0.45', and another leading to an 'InGaAs detector' through a 'lens'. Figure 3: Diagram of setup to measure Raman amplification Grubb uses a germanosilicate fiber coupled to the WDM to wavelength shift the 1064 nm pump signal. (Grubb, pp. PD3-2, PD3-4; Figure 1).

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Claim Term	References
	Figure 1 consists of two schematic diagrams, (a) and (b), illustrating optical fiber amplifiers. Diagram (a) shows a third-order cascaded Raman laser. It features a pump input at 1060 nm, a fiber with a core diameter of 1064 μm, and a series of fiber gratings. The output is at 1240 nm. A PD3-4 detector is shown at the output. Diagram (b) shows a third-order intracavity-pumped cascaded 1.3 μm Raman amplifier. It features a pump input at 1064 nm, a fiber with a core diameter of 1064 μm, and a series of fiber gratings. The output is at 1.3 μm. A PD3-4 detector is shown at the output. The diagrams are labeled with various wavelengths and components, including '1240 nm HR', '1117', '1175', '1310/1064 WDM', 'Fiber Bragg gratings', '1.3 μm signal in', '1064 nm pump in', '1.3 μm signal out', and '1240 nm output coupler'.
	Figure 1: a) schematic of the third-order (1240 nm) cascaded Raman laser, b) third-order intracavity-pumped cascaded 1.3 μm Raman amplifier.
	In the '404 Patent, the combined light in fiber 43 (the first optical signal) is coupled into a fiber amplifier (471, 461, 451, 452, 462, 472). ('404 Patent, Col. 6:16-32; Figure 4).
	In the '369 Patent, the combined light from beamsplitter 67 (the combiner) is coupled into fiber 63. ('369 Patent, Col. 10:16-20; Figure 3).
	The '903 Patent states that three different fiber configurations can be used in the embodiment of Figure 9—Figs. 9a-c. Figure 9b of the '903 Patent shows a wavelength shifter comprising two fibers having different zero-dispersion wavelength; thus, comprising first and second waveguide structures. The '903 Patent states in relation to Fig. 9b that "two fibers spliced together with one fiber having a zero-

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	dispersion wavelength at about 1310 nm (first cascade) and the other at 1390 nm (second cascade).” FIG. 9b Fidric discloses a cascaded Raman resonator—“[i]n a preferred version of this embodiment, a set of reflectors is used in the form of a cascaded Raman resonator, such that a shorter wavelength initial pump signal is converted to progressively longer wavelengths.” (Fidric, p. 5, ll. 5–8). Furthermore, Fidric states that “[a]fter exiting the erbium-doped amplifier stage 1128, the optical signal enters an amplifier stage consisting of an erbium-doped gain medium 1123 and a Raman-shifting gain medium 1132. The Raman gain medium 1132 is pumped with optical pump energy at a wavelength of 1117 nm that is coupled into the gain medium 1132 from pump source 1134 via WDM 1136.” (Fidric, p. 13, ll. 11–15). FIG. 11

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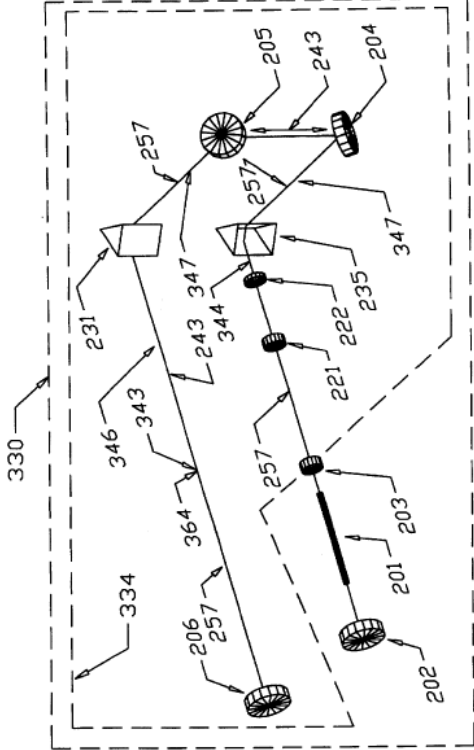
Claim Term	References
	The '778 Patent states that "[i]n one aspect of the intracavity feature, the pump cavity 330 and both of the Stokes cavities 331 and 332 overlap inside a Raman cell 336 (FIG. 25), which may have the features of the above-described Raman cells (e.g., the Raman cell 111)." ('778 Patent, Col. 26:45-50).  FIG. 26

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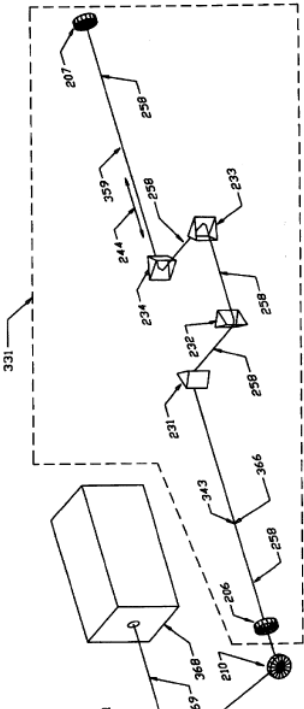
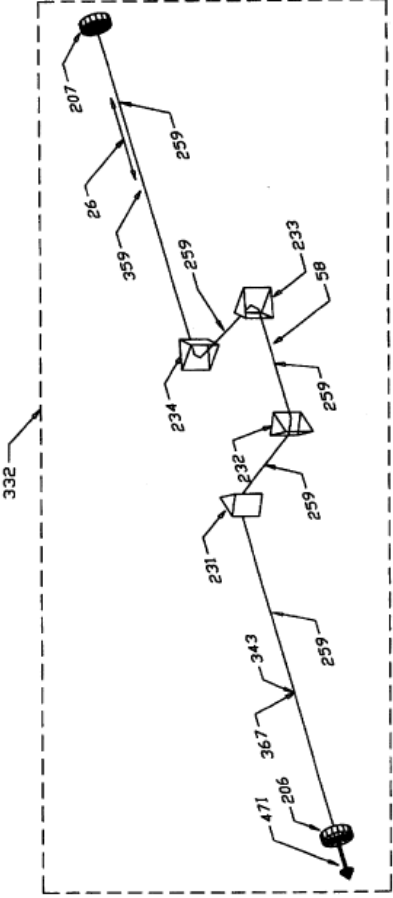
Claim Term	References
	 FIG 28  FIG 29 Price discloses an optical fiber “arranged to receive the ultrashort optical pulses, amplify the ultrashort optical pulses, and alter the wavelength of the ultrashort optical pulses to at least the second wavelength by the soliton-self-frequency shifting effect.” (Price, p. 10, claim 1; p. 2, [0012]). Page 45 of 85 OMNI Ex. 2008 IPR2025-00839

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	Price further states that “the holey fiber is selected to have anomalous dispersion over at least the whole of the wavelength range of interest, that is, from the wavelength of the ultrashort pulses generated by the optical source (first wavelength) to the maximum wavelength to which it is desired to shift the pulses (second wavelength).” (Price, p. 7, [0093]). Thus, the holey fiber of Price constitutes a wavelength shifter. It is coupled to the one or more combiners (Price, p. 5, [0071]) (“A dichroic mirror 54 is provided for coupling light into the holey fiber 48”). The ’636 Patent states that “[d]isposed along line 12 downstream from the signal source are a plurality of multiple-order Raman amplifiers 10 distributed along the length of line 12. The amplifiers 10 are preferably disposed intermediate ends of continuous fiber segments.” (’636 Patent, Col. 3:31–35). Islam2002 states that “[d]ue to the frequency downshift (wavelength upshift) of the Raman effect, the wavelength of the light source 26 is upshifted to match that of the signal.” (Islam2002, p. 5, ¶ 73). “As previously noted, the Raman amplifier is capable of cascading through multiple orders. With each cascade order there is a corresponding shift in optical wavelength. The wavelength shift corresponds to a predetermined Stokes wavelength. Thus to achieve a 1310 nm signal wavelength four cascaded orders of Stokes shift would be employed, namely: 1117 nm to 1175 nm to 1240 nm to 1310 nm. Similarly, a fifth Stokes shift, based on the previous cascaded orders, would produce an output wavelength at 1480 nm.” (Islam2002, p. 6, ¶ 79).
a first waveguide structure and	In Shaw’s Example 1, the As-Se fiber 210 is an optical fiber, so it is a “waveguide structure” within the meaning of the claim. In the ’310 Patent, 63A in Figure 22 is a single-mode fiber, and more specifically a Raman fiber laser, which is a type of waveguide structure. (’310 Patent, Col. 22:1–3).

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	In the '806 Patent, the Yb-doped fiber amplifier 90' is a waveguide structure within the meaning of the claim. In Thielen, the As-Se fiber is an optical fiber, so it is a "waveguide structure" within the meaning of the claim. In Grubb, the germanosilicate fiber is an optical fiber, so it is a "waveguide structure" within the meaning of the claim. In the '404 Patent, the fiber amplifier (471, 461, 451, 452, 462, 472) is a waveguide structure within the meaning of the claim. In the '369 Patent, fiber 63 is a waveguide structure within the meaning of the claim. The first fiber of the two fibers shown in Fig. 9b of the '903 Patent ($\lambda_o \sim 1310\text{nm}$) constitutes a first waveguide structure. Furthermore, the '903 Patent states that "wherein said distributed gain medium comprises first and second optical fibers spliced together, and said optical fibers are used for two different cascaded Raman orders" ('903 Patent, Claim 18, Col. 14:29–32). The Raman-shifting gain medium 1132 in Fidric constitutes a first waveguide structure. <i>See</i> Fig. 11. The '778 Patent states that "[a]pplicant provides a first Stokes cavity for the first Raman shift. The first Stokes cavity overlaps the tunable laser pump cavity such that the intensity in the first Stokes cavity is increased." ('778 Patent, Col. 2:42–45). Price discloses a holey fiber (element 48), which constitutes a first waveguide structure. Fig. 18a in Islam2002 shows a wavelength shifter comprising two fibers spliced together (labelled "CROSS-SPLICE" in the drawing):

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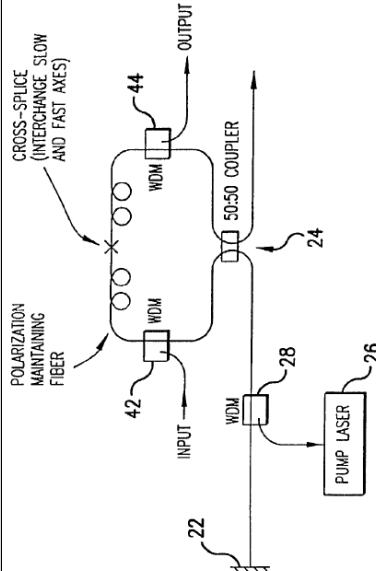
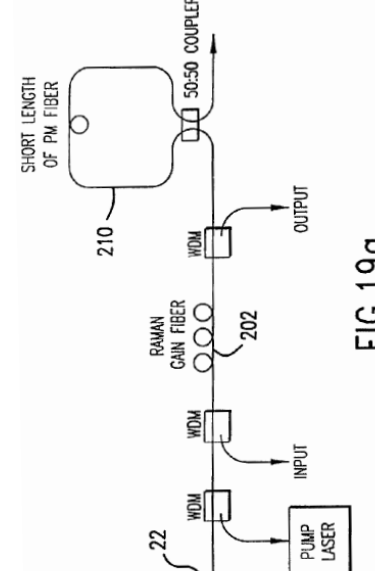
Claim Term	References
	 FIG. 18a Fig. 19a shows a Raman gain fiber (element 202) followed by a short length of PM fiber (element 210):  FIG. 19a
a second waveguide structure,	Shaw describes how his process can be used in sequence to upshift an initial pump beam multiple times using multiple fibers: “The latter embodiment involves cascading several Fabry-Perot cavities such that the output Stokes from one cavity is trapped in the next Fabry Perot cavity that generates and amplifies a second Stokes at longer

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	wavelength. With this process, the initial pump beam may be shifted up in wavelength through several Stokes shifts to generate a high power beam at wavelengths corresponding to multiples of the Raman shift.” (Shaw, p. 3, ¶ 36). Shaw also describes how different types of fibers (e.g., silica and chalcogenide fibers). (Shaw, p. 3, ¶¶ 30–31). Shaw describes many different types of chalcogenide and chalcohalide fibers that can be used: “Chalcogenide glasses comprise at least one of the chalcogenide elements sulfur (S), selenium (Se), and tellurium (Te) and typically further include at least one of Ge, As, Sb, Ti, Pb, Ba, Si, P, Ga, In, Cl, Br, an I. Chalcogenide glass typically contains at least 25 mole %, and more typically at least 50 mole % of one or more of the three chalcogenide elements but less than about 90 mole %, and typically less than 80 mole %. As used herein, the term ‘chalcogenide glass’ includes chalcohalide glass.” (Shaw, p. 2, ¶ 22). Shaw, therefore, discloses the concept of using multiple waveguides to achieve larger wavelength shifts. In the ’310 Patent, 63B in Figure 22 is another Raman fiber laser. (’310 Patent, Col. 22:10–13). The ’806 Patent describes having a second fiber 901 (a fused silica fiber doped with Germanium) that is coupled to the output of the Yb-doped fiber amplifier 90’. (’806 Patent, Col. 18:6–9). This fiber 901 is also a waveguide structure. In the ’404 Patent, the inventors describe how subsequent fiber amplifiers can be cascaded (i.e., added) to the system. (’404 Patent, Col. 7:31–40). The ’404 Patent, therefore, discloses the concept of using multiple waveguides. In the ’369 Patent, fiber amplifier 53 is a second waveguide structure within the meaning of the claim. (’369 Patent, Col. 10:24–26). The second fiber of the two fibers shown in Fig. 9b in the ’903 Patent ($\lambda_o \sim 1390\text{nm}$) constitutes a second waveguide structure. Furthermore, the ’903 Patent states that “wherein said distributed gain medium comprises first and second optical fibers

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	spliced together, and said optical fibers are used for two different cascaded Raman orders” (Claim 18, Col. 14:29–32). The erbium-doped gain medium 1123 in Fidric constitutes a second waveguide structure. <i>See</i> Fig. 11. The ’778 Patent states that “[f]urther, a second Stokes cavity overlaps the pump cavity and is provided with one highly reflecting end mirror and one partially reflecting end mirror which serves as an output coupler.” (’778 Patent, Col. 2:45–48). Fig. 18a in Islam 2002 shows a wavelength shifter comprising two fibers spliced together (labelled “CROSS-SPLICE” in the drawing): FIG. 18a Fig. 19a shows a Raman gain fiber (element 202) followed by a short length of PM fiber (element 210):

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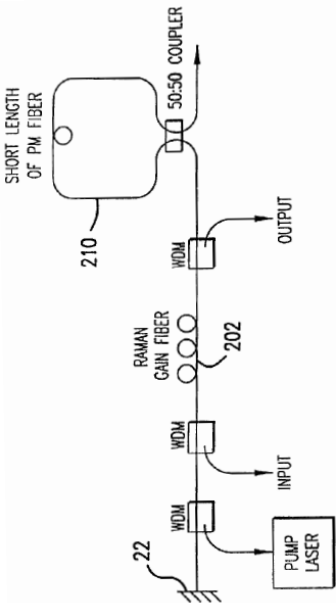
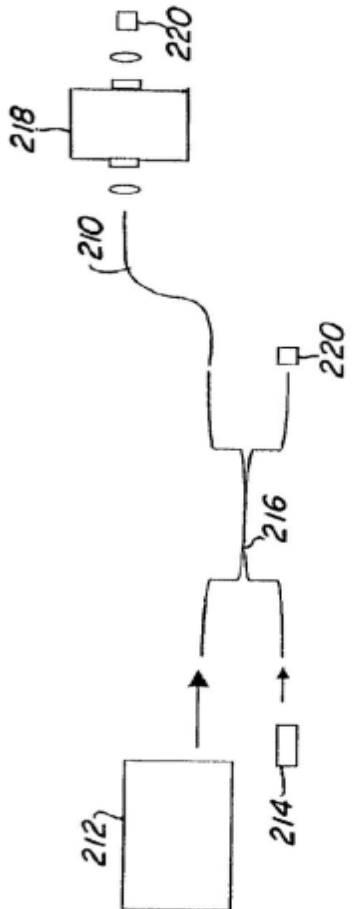
Claim Term	References
	 FIG. 19a
the wavelength shifter operable to receive the first optical signal and	In Shaw's Example 1, the As-Se fiber 210 is coupled to the 2x2 coupler 216, which creates the "first optical signal" (first pump signal + second pump signal). (Shaw. p. 4, ¶ 41; Figure 8).  FIG. 8

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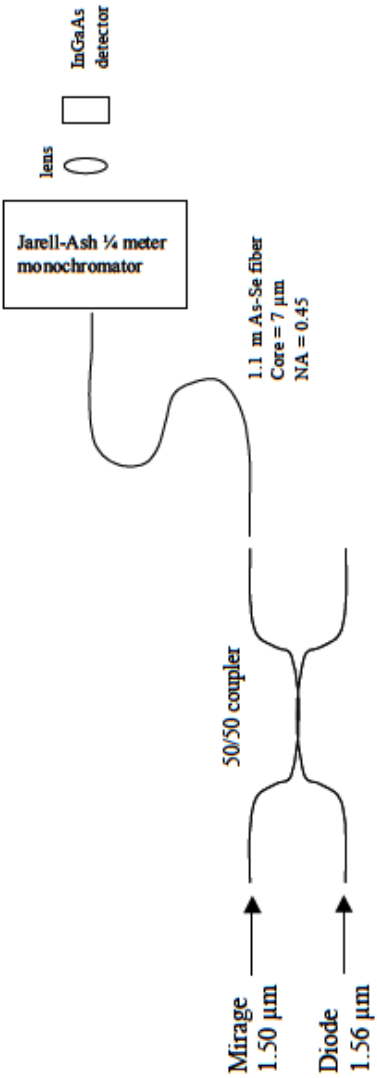
Claim Term	References
	In the '310 Patent, Raman fiber lasers 63A and 63B in Figure 22 receive light from the light source 62C. ('310 Patent, Col. 21:67–22:13).
	In the '806 Patent, the Yb-doped fiber amplifier 90' receives the combined seed and pump laser pulses. ('806 Patent, Col. 17:65–18:5).
	The As-Se fiber in Thielen (the “wavelength shifter”) is coupled to the 50/50 coupler and, therefore, receives the first optical signal (the combine pump signals). “The seed signal to be amplified, a low power 1.56 μm laser diode, was coupled along with the pump source into a 50/50 silica fiber coupler. One of the output ports was butt-coupled to the As-Se fiber.” (Thielen, p. 75; Figure 3).
	 The diagram illustrates the experimental setup for measuring Raman amplification. At the bottom, two input sources are shown: a 'Mirage 1.50 μm' laser and a 'Diode 1.56 μm' laser. Arrows from both point to a '50/50 coupler'. The output of the coupler is a single line that enters a '1.1 m As-Se fiber' with 'Core = 7 μm' and 'NA = 0.45'. The fiber is represented by a wavy line. The output of the fiber is connected to a 'Jarell-Ash ¼ meter monochromator'. The light then passes through a 'lens' (represented by a circle) and is detected by an 'InGaAs detector'.

Figure 3: Diagram of setup to measure Raman amplification

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	The germanosilicate fiber in Grubb receives the combined 1064 nm and 1.3 μm light from the WDM. (Grubb, p. PD3-4; Figure 1). The fiber amplifier in the '404 Patent receives the combined 1.064 μm and 1.310 μm light from the WDM. ('404 Patent, Col. 6:16–31; Figure 4). In the '369 Patent, fiber 63 receives the combined light (λ_p and λ_s—the first optical signal). ('369 Patent, Col. 10:16–20). In the embodiment shown in Fig. 9 of the '903 Patent, the wavelengths shifter (element 30) is operable to receive the first optical signal. It is noted that optical fiber 30 can be embodied as any of the variants shown in Figs. 9a, 9b, 9c. Accordingly, fiber 30 can be two fibers spliced together as shown in Fig. 9b and described in Col. 9:27–35. Furthermore, the embodiments shown in Figs. 10–11 of the '903 Patent both show a Raman gain fiber (element 65 and 105, respectively) operable to receive the first optical signal (combined in WDM2). The Raman gain fiber may be embodied as cascaded fibers to achieve cascaded Raman shifts as described throughout the '903 Patent, e.g. “said first pumping light cascades through said first distributed gain medium a plurality of Raman orders” ('903 Patent, Claim 1, Col. 12:32–33). Also, the '903 Patent states that “The Raman gain fiber has the same characteristics as described above for the open-loop design.” ('903 Patent, Col. 10:5–6; <i>see also</i> Col. 10:22–31). Thus, the two-fiber design of Fig. 9b may be utilized in any of the embodiments shown in Figs. 10–11. Fidric states that “the optical signal enters an amplifier stage consisting of an erbium-doped gain medium 1123 and a Raman-shifting gain medium 1132.” (Fidric, p. 13, ll. 11–13).

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	The '778 Patent states that "[t]he amplified initial laser pulse 41 has a nominal 0.0004 nm bandwidth and forms the input to a Raman device 109 of the laser pulse generator 70." ('778 Patent, Col. 15:45–47). The '778 Patent further states that "[t]he prisms 233 and 234 recombine the two Stokes beams 244 and 246 from their separated condition at position 358, so that when combined they are coaxial at position 359. The mirror 207 is a high reflector at both the wavelength of the first Stokes beam 244 and that of the second Stokes beam 246. The front surface of the mirror 207 is concave to focus both Stokes beams 244 and 246 back to the position 343 in the Raman cell 336." ('778 Patent, Col. 28:54–61). Price states that "[t]he ultrashort optical pulses 43 are generated by the optical source 12, and are coupled into the holey fiber 48 of the amplifier 14 together with the pump radiation 49 generated by the pump laser 16." (Price, p. 6, [0086]). Thus, holey fiber 48 is operable to receive the first optical signal. The wavelength shifter is evident from Figs. 18a and 19a in Islam2002, as well as the cited paragraphs below: "This light is introduced through the wavelength division multiplexing (WDM) coupler 28. The optical signal to be amplified, injected through WDM coupler 42, may be at a wavelength of 1300 nm to 1310 nm. The injected signal propagates in the clockwise direction around loop 30 and is then removed using WDM coupler 44." (Islam2002, p. 5, ¶ 73). "The light source 26 is a pumped fiber laser coupled through a WDM port 28 to the optical resonator. An optical signal is injected into the optical resonator and this signal is then amplified by the optical energy introduced by the light source 26." (Islam2002, p. 5, ¶ 72).
to wavelength shift at least a portion of the first optical signal	In Shaw's Example 1, the As-Se fiber 210 shifts light from the first pump signal (at 1.5 μm) to the second wavelength (at 1.56 μm) using the stimulated Raman scattering

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based at least in part on a Raman effect,	effect. (Shaw, p. 4, ¶ 41). While Defendant contends that this term is indefinite, Shaw does state that a Raman effect is used in the shifting process. The '310 Patent describes how the Raman lasers use the Raman effect to shift the wavelengths. "In order to increase this bandwidth further so as to provide additional fiber laser outputs for WDM combining, Raman shifting of wavelengths within band 69 can be utilized which is exemplified in conjunction with Raman fiber lasers 63A and 63B of FIG. 22." ('310 Patent, Col. 21:35–42, 60–64). The '806 Patent states that the wavelength shift of the seed laser pulse from 1.064 μm to 1.120 μm occurs via the Raman effect. "Wavelength shifting occurs when a pump beam co-propagating with a signal beam has a wavelength difference equal to the energy difference corresponding to the 'Raman Energy' associated with a vibrational states." ('806 Patent, Col. 17:3–8). Thielen states that the wavelength shift in the As-Se fiber is due to spontaneous Raman scattering. "This scan shows a broad peak of about 1 mV attributed to amplified spontaneous Raman scattering." (Thielen, p. 76; Figure 4).

Figure 4: Experimental results showing the spectra of the pump, unamplified signal, background amplified spontaneous Raman scattering, and the amplified signal.

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	Grubb states that the 1064 nm light is shifted to 1.3 μm (the 4th Stokes line) via a Raman effect. (Grubb, p. PD3-2). The '404 Patent states that the 1.064 μm light is shifted to 1.310 μm by the stimulated Raman scattering (SRS) effect. ('404 Patent, Col. 6:16–31, Col. 3:24–56). The '903 Patent states in Example 1 that “Raman effect leads to a transfer of energy from one optical beam (the pump) to another optical beam (the signal). The signal is downshifted in frequency (or upshifted in wavelength) by an amount determined by vibrational modes of silica fibers.” ('903 Patent, Col. 4:56–58). Additionally, the '903 Patent states in Example 2 that “The nonlinear polarization effect is distributed throughout the dielectric, resulting in a cascading series of wavelength shifts as energy at one wavelength excites a vibrational mode that produces light at a longer wavelength.” ('903 Patent, Col. 5:14–18). The '903 Patent states in relation to Fig. 6: “The basic concept of the broadband NLPA is illustrated in Fig. 6. Starting from the pump wavelength λ_p cascaded Raman amplification can be used in the first few stages.” ('903 Patent, Col. 7:10–12). Fidric states that “this portion of the system functions as a “cascaded Raman resonator” (CRR), progressively shifting the initial pump wavelength to longer wavelengths until a desired pumping wavelength of 1470 nm is reached.” (Fidric, p. 13, ll. 17–20). While Defendant contends that this term is indefinite, the '778 Patent does state that a Raman effect is used in the shifting process: “[t]he present invention uses Raman scattering techniques. As a preface to the following description of the present invention, Raman scattering techniques are discussed in reference to FIG. 2.” ('778 Patent, Col. 6:14–17). The '778 Patent further states that “[o]utput light resulting from one Raman shift is called the Stokes or the first Stokes, or the first Stokes pulse. Output light resulting

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	from two Raman shifts is called the second Stokes or the second Stokes pulse.” (’778 Patent, Col. 6:22–27). While Defendant contends that this term is indefinite, Price does state that a Raman effect is used in the shifting process: “[t]he Raman soliton pulse is a stable entity, which, due to the SSFS effect, continuously downshifts its central frequency (moves to longer wavelengths) as it moves along the amplifier 14.” (Price, p. 6, [0090]). Price states that “a wide range of pulsed sources are suitable for use in the present invention, given the minimal limitations on both power and wavelength. For example, wavelength shifting of relatively low energy pulses directly from a simple diode-pumped fiber oscillator is possible.” (Price, p. 1, [0009]). While Defendants contend that this term is indefinite, Islam2002 does state that a Raman effect is used in the shifting process: “Due to the frequency downshift (wavelength upshift) of the Raman effect, the wavelength of the light source 26 is upshifted to match that of the signal.” (Islam2002, p. 5, ¶ 73). “Raman gain results from the interaction of intense light with optical phonons in the glass, and the Raman effect leads to a transfer of energy from one optical beam (the pump) to another optical beam (the signal). An interesting property of Raman gain is that the signal is downshifted in frequency (upshifted in wavelength) by an amount determined by the vibrational modes of the glass.” (Islam2002, p. 4, ¶ 65).
wherein the wavelength shifter operates to wavelength shift at least the first wavelength to an intermediate optical wavelength in the first waveguide structure and	In Shaw’s Example 1, the As-Se fiber 210 shifts light from the first pump signal (at 1.5 μm) to the second wavelength (at 1.56 μm) using the stimulated Raman scattering effect. (Shaw, p. 4, ¶ 41). While Defendant contends that this term is indefinite, Shaw does state that a Raman effect is used in the shifting process.

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	The '310 Patent describes an example wherein the initial source light from laser 62C at a wavelength of 1100 nm is shifted in Raman fiber laser 63A to 1160 nm. ('310 Patent, Col. 21:64–22:13). In the '806 Patent, the Yb-doped fiber amplifier 90' shifts the seed laser pulse wavelength from 1.064 μm to 1.120 μm. ('806 Patent, Col. 18:2–5). In Thielen, light from the 1.50 μm pump (the first wavelength) is shifted via spontaneous Raman scattering to 1.56 μm (an intermediate optical wavelength). In Grubb, the light from the 1064 nm pump (the first wavelength) is shifted via the Raman effect to 1.3 μm (an intermediate optical wavelength). In the '404 Patent, the light from the 1.064 μm pump (the first wavelength) is shifted via the stimulated Raman scattering effect to 1.310 μm (an intermediate optical wavelength). The '903 Patent states that “Second, FIG. 9b, two fibers spliced together with one fiber having a zero-dispersion wavelength at about 1310 nm (first cascade) and the other at 1390 nm (second cascade)” ('903 Patent, Col. 9:30–33). Thus, the first cascade happens in the first fiber [of the two-fiber embodiment], and the second cascade happens in the second fiber. The '903 Patent further states that “said first pumping light cascades through said first distributed gain medium a plurality of Raman orders including an intermediate order” ('903 Patent, Claim 1, Col. 12:32–34). The '903 Patent further states that “The pumping light cascades through the distributed gain medium a plurality of Raman orders including an intermediate order having a wavelength λ_r, at a close proximity to the zero-dispersion wavelength λ_0 to phase match four-wave mixing (if $\lambda_r < \lambda_0$) or parametric amplification (if $\lambda_r > \lambda_0$)” ('903 Patent, Col. 10:49–54).

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	The '903 Patent further states that "To achieve the broad bandwidth, one intermediate order of the Raman cascade is arranged to be at a close proximity to the zero-dispersion wavelength of an amplifying fiber" ('903 Patent, Col. 2:47–49). Thus, the intermediate order of the Raman cascade constitutes an intermediate optical wavelength in the first waveguide structure. "In a preferred version of this embodiment, a set of reflectors is used in the form of a cascaded Raman resonator, such that a shorter wavelength initial pump signal is converted to progressively longer wavelengths." (Fidric, p. 5, ll. 5–8). Fidric discloses that the wavelength is progressively shifted to longer wavelengths in the Raman-shifting gain medium, inherently therefore also including an intermediate optical wavelength. The '778 Patent states that "[a]pplicant provides a first Stokes cavity for the first Raman shift. The first Stokes cavity overlaps the tunable laser pump cavity such that the intensity in the first Stokes cavity is increased." ('778 Patent, Col. 2:43–46). The '778 Patent further states that "[t]he Raman device 43 is provided with medium 45, such as H₂, which Raman shifts the initial pulse 41 to form a first Stokes pulse 46, which has a wavelength tunable from 1.09 to 1.72 microns." ('778 Patent, Col. 8:9–12). The '778 Patent further states that "the first pulse 46 having a wavelength of 1.4 microns...the initial pulse 41 having a wavelength of 885 nm." ('778 Patent, Col. 10:18–21). The '778 Patent further states that "[i]f the initial laser pulse 41 is at 900 nm (or a wavenumber of 11,111.11 cm⁻¹), then the first Raman shift in hydrogen will be to (11,111.11 cm⁻¹–4155 cm⁻¹) = 6956.11 cm⁻¹. This corresponds to 1.437 microns. The second Raman shift in H₂ will be to (6956.11 cm⁻¹–4155 cm⁻¹) = 2801.11 cm⁻¹, corresponding to 3.570 microns, which is within the design output wavelength of the second Stokes pulse 47." ('778 Patent, Col. 12:61–13:1). The '778 Patent further states that "[t]he wavelength (900 nm in this example) of the initial pump pulse 41 is double Raman shifted in Step 166. The first Raman shift in this example is to (11,111.11 cm⁻¹–4155 cm⁻¹) = 6956.11 cm⁻¹ and the second Raman shift in this example is to (6956.11 cm⁻¹–4155 cm⁻¹) = 2801.11 cm⁻¹ (corresponding to 3.570

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	microns), which is in the range 48 of from nominally 2 to 6 microns to form the output laser pulse 47.” (’778 Patent, Col. 23:12–19). The ’778 Patent further states that “[l]aser light which results from one Raman shift of the pump beam 243 is referred to as the first Stokes light or beam 244.” (’778 Patent, Col. 26:24–26). Price states that: “the ultrashort optical pulses are delivered to the optical fiber of the optical fiber amplifier with sufficient power for the soliton-self-frequency shifting effect to alter the wavelength of the ultrashort pulses to the second wavelength and to one or more additional wavelengths within the wavelength range of the anomalous dispersion of the optical fiber of the optical fiber amplifier.” (Price, p. 2, [0019]). Islam2002 states “to achieve a 1310 nm signal wavelength four cascaded orders of Stokes shift would be employed, namely: 1117 nm to 1175 nm to 1240 nm to 1310 nm. Similarly, a fifth Stokes shift, based on the previous cascaded orders, would produce an output wavelength at 1480 nm.” (Islam2002, p. 6, ¶ 79).
to wavelength shift the intermediate optical wavelength to a longer optical wavelength in the second waveguide structure;	Shaw describes how his process can be used in sequence to upshift an initial pump beam multiple times using multiple fibers: “The latter embodiment involves cascading several Fabry-Perot cavities such that the output Stokes from one cavity is trapped in the next Fabry Perot cavity that generates and amplifies a second Stokes at longer wavelength. With this process, the initial pump beam may be shifted up in wavelength through several Stokes shifts to generate a high power beam at wavelengths corresponding to multiples of the Raman shift.” (Shaw. p. 3, ¶ 36). Shaw also describes how different types of fibers (e.g., silica and chalcogenide fibers). (Shaw, p. 3, ¶¶ 30–31). Shaw describes many different types of chalcogenide and chalcohalide fibers that can be used: “Chalcogenide glasses comprise at least one of the chalcogenide elements sulfur (S), selenium (Se), and tellurium (Te) and typically further include at least one of Ge, As, Sb, Tl, Pb, Ba, Si, P, Ga, In, Cl, Br, an I. Chalcogenide glass typically contains at least 25 mole %, and more typically at least 50 mole % of one or more of the three chalcogenide elements but less than about 90

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	mole %, and typically less than 80 mole %. As used herein, the term 'chalcogenide glass' includes chalcohalide glass." (Shaw, p. 2, ¶ 22). Shaw, therefore, discloses the concept of using a second waveguide to shift the light from the first waveguide structure (the intermediate optical wavelength) to a longer optical wavelength in the second fiber (second waveguide structure). The '310 Patent describes how the intermediate wavelength is further shifted in the second waveguide (Raman laser 63B) to a wavelength of 1220 nm. ('310 Patent, Col. 22:10–20). The '903 Patent states that "one fiber having a zero-dispersion wavelength at about 1310 nm (first cascade) and the other at 1390 nm (second cascade)." Thus, the wavelength is shifted to a longer wavelength by a second Raman cascade in the second fiber. The '903 Patent states in Example 2 that "Cascading is the mechanism by which optical energy at the pump wavelength is transferred, through a series of nonlinear polarizations, to an optical signal at a longer wavelength.... The nonlinear polarization effect is distributed throughout the dielectric, resulting in a cascading series of wavelength shifts as energy at one wavelength excites a vibrational mode that produces light at a longer wavelength. This process can cascade through numerous orders." ('903 Patent, Col. 5:14–19). The '903 Patent further states that "said second pumping light cascades through said second distributed gain medium a plurality of Raman orders including an intermediate order" ('903 Patent, Claim 1, Col. 12:52–54). Fidric states that the cascaded Raman resonator (CRR) is configured for "progressively shifting the initial pump wavelength to longer wavelengths until a desired pumping wavelength of 1470 nm is reached" (Fidric, p. 13, ll. 18–20).

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	Furthermore, Fidric states that “A second rare earth doped stage may also be used in combination with the other stages.” (Fidric, p. 5, ll. 18–19). The ’778 Patent states that “the photons then accumulate at the desired second Stokes wavelength, resulting in high conversion efficiency to the 2 to 6 micron output laser pulse 47.” (’778 Patent, Col. 13:26–29). The ’778 Patent further states that “laser light which results from two Raman shifts of the pump beam 243 is referred to as the second Stokes light or beam 246, which may be in the form of pulses depicted by arrow 252 in FIG. 24.” (’778 Patent, Col. 26:27–30). The ’778 Patent further states that “[t]he second Stokes pulse 47 is nominally at any wavelength within an output range 48 (FIG. 14a) of 2 to 6 microns.” (’778 Patent, Col. 8:16–17). The ’778 Patent further states that “the second Stokes pulse in generating a 3.35 micron second Stokes output laser pulse.” (’778 Patent, Col. 4:63–65). The ’778 Patent further states that “[t]he wavelength of the initial pump pulse 41 is double Raman shifted in Step 159 into the range 48 of from nominally 2 to 6 microns to form the output laser pulse 47 having any given wavelength within the range 48. The shifting is performed by the Raman devices 43 or 109, for example, having the H2 medium 45 (or other Raman gas). The Raman devices 43 or 109 operate in response to the initial laser pulse 41 to generate the first Stokes pulse 46 and the second Stokes pulse 47.” (’778 Patent, Col. 22:24–32). Price states that “the ultrashort optical pulses are delivered to the optical fiber of the optical fiber amplifier with sufficient power for the soliton-self-frequency shifting effect to alter the wavelength of the ultrashort pulses to the second wavelength and to one or more additional wavelengths within the wavelength range.” (Price, p. 2, [0019]). The “one or more additional wavelengths” anticipates “a longer optical wavelength.” Islam2002 states “to achieve a 1310 nm signal wavelength four cascaded orders of Stokes shift would be employed, namely: 1117 nm to 1175 nm to 1240 nm to 1310

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	nm. Similarly, a fifth Stokes shift, based on the previous cascaded orders, would produce an output wavelength at 1480 nm.” (Islam2002, p. 6, ¶ 79).
wherein at least a portion of the intermediate optical wavelength is greater than the first wavelength and	In Shaw’s Example 1, the light shifted by the As-Se fiber 210 from the pump wavelength (1.5 μm) to the signal wavelength (1.56 μm) would satisfy this limitation. The intermediate optical wavelength (1.56 μm) is longer than the first wavelength (1.5 μm). In the ’310 Patent, the intermediate wavelength would be the wavelength after the first Raman fiber laser 63A (1160 nm), which is greater than the initial laser wavelength (1100 nm) from laser 62C. In the ’806 Patent, the 1.120-μm wavelength is longer than the seed wavelength of 1.064 μm. In Thielen, the shifted 1.56 μm light (the intermediate optical wavelength) is longer than the 1.50 μm light (the first wavelength). In Grubb, the shifted 1.3 μm light (the intermediate optical wavelength) is longer than the 1064 nm light (the first wavelength). In the ’404 Patent, the shifted 1.310 μm light (the intermediate optical wavelength) is longer than the 1.064 μm light (the first wavelength). Table 1 of the ’903 Patent provides a list of various Raman orders when pumping between 1060 and 1140 nm. (’903 Patent, Col. 8:5–42). The ’903 Patent states that “To obtain gain between 1430 nm and 1520 nm, the pump is operated between 1090 nm and 1140 nm, and five cascaded Raman orders are used to reach the desired wavelength. To make use of the broadening from PA or 4 WM, a pumping scheme is

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	selected in the middle of this range, i.e., starting with a pump wavelength of 1117 nm. Then, the various Raman orders land at approximately 1175 nm, 1240 nm, 1310 nm, 1390 nm and finally 1480 nm.” (’903 Patent, Col. 8:43–57). “In a preferred version of this embodiment, a set of reflectors is used in the form of a cascaded Raman resonator, such that a shorter wavelength initial pump signal is converted to progressively longer wavelengths.” (Fidric, p. 5, ll. 5–8). The ’778 Patent states that “[t]he initial pulse 41 may have a wavelength tunable in a 750 to 1000 nm nominal pump wavelength band 44.... The Raman device...shifts the initial pulse 41 to form a first Stokes pulse 46, which has a wavelength tunable from 1.09 to 1.72 microns.” (’778 Patent, Col. 8:7–12). A wavelength of 1.09 to 1.72 microns is greater than 750 to 1000 nm. Price states that “[t]he Raman soliton pulse is a stable entity, which, due to the SSFS effect, continuously downshifts its central frequency (moves to longer wavelengths) as it moves along the amplifier 14.” (Price, p. 4, [0056]). Price further states that “at higher pump powers the resultant change in gain distribution causes the Raman solitons to form earlier within the holey fiber, thereby leaving the solitons a greater length of fiber within which to walk-off to longer wavelengths through SSFS.” (Price, p. 7, [0098]). Price further states that “FIG. 12(a) shows spectra (as plots of intensity I against wavelength λ) of the pulses from the optical source at the first wavelength, of 1.06 μm, and of pulses output from the amplifier, at a second wavelength of 1240 nm.” (Price, p. 7, [0100]). The second wavelength of 1240 nm is greater than the first wavelength of 1.06 μm.

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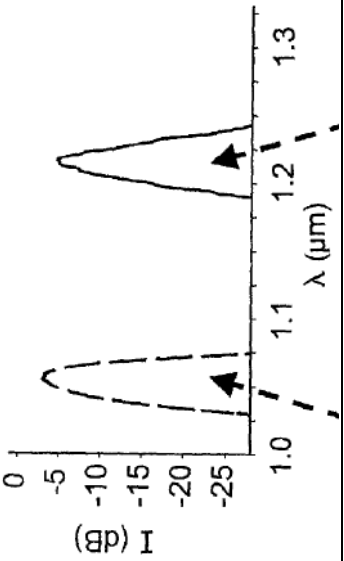
Claim Term	References
	 Fig. 12a Islam2002 states “to achieve a 1310 nm signal wavelength four cascaded orders of Stokes shift would be employed, namely: 1117 nm to 1175 nm to 1240 nm to 1310 nm. Similarly, a fifth Stokes shift, based on the previous cascaded orders, would produce an output wavelength at 1480 nm.” (Islam2002, p. 6, ¶ 79).
wherein at least a portion of the longer optical wavelength is greater than the intermediate optical wavelength; and	As noted above with Shaw, using a second fiber (second waveguide structure) will shift the wavelength of the intermediate optical wavelength to a longer optical wavelength. So, the output from the second waveguide (the longer optical wavelength) will be at a longer wavelength than the input to the second waveguide (the intermediate optical wavelength). In the '310 Patent, the longer optical wavelength (1220 nm) would be the light emitted from the second Raman fiber laser 63B, which is longer than the intermediate light emitted from the first Raman fiber laser 63A (1160 nm). As noted above with respect to the '903 Patent, each Raman order occurs at a longer optical wavelength than the previous one; thus, the example of five Raman orders at “1175 nm, 1240 nm, 1310 nm, 1390 nm and finally 1480 nm” falls within the scope of this element. Fidric states that “this portion of the system functions as a “cascaded Raman resonator” (CRR), progressively shifting the initial pump wavelength to longer

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	wavelengths until a desired pumping wavelength of 1470 nm is reached.” (p. 13, ll. 17–20). “In a preferred version of this embodiment, a set of reflectors is used in the form of a cascaded Raman resonator, such that a shorter wavelength initial pump signal is converted to progressively longer wavelengths.” (Fidric, p. 5, ll. 5–8). Fidric discloses that the wavelength is progressively shifted to longer wavelengths in the Raman-shifting gain medium, inherently therefore also including an intermediate optical wavelength. The ’778 Patent states that “[t]he second Stokes pulse 47 is nominally at any wavelength within an output range 48 (FIG. 14a) of 2 to 6 microns.” (’778 Patent, Col. 8:15–17). A wavelength of 2 to 6 microns is greater than 1.09 to 1.72 microns. Price states that “the ultrashort optical pulses are delivered to the optical fiber of the optical fiber amplifier with sufficient power for the soliton-self-frequency shifting effect to alter the wavelength of the ultrashort pulses to the second wavelength and to one or more additional wavelengths within the wavelength range of the anomalous dispersion of the optical fiber” (Price, p. 2, [0019]). Price further states that “The Raman soliton pulse is a stable entity, which, due to the SSFS effect, continuously downshifts its central frequency (moves to longer wavelengths) as it moves along the amplifier” (Price, p. 4, [0056]). Price further states that “Raman solitons form and are continuously wavelength shifted through the SSFS effect” (Price, p. 4, [0061]). The disclosure of shifting to ‘one or more additional wavelengths’ and ‘continuously downshifts its central frequency’ implies that the longer optical wavelength is greater than the intermediate optical wavelength. Islam2002 states “to achieve a 1310 nm signal wavelength four cascaded orders of Stokes shift would be employed, namely: 1117 nm to 1175 nm to 1240 nm to 1310

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	nm. Similarly, a fifth Stokes shift, based on the previous cascaded orders, would produce an output wavelength at 1480 nm.” (Islam2002, p. 6, ¶ 79).
wherein the first waveguide structure is substantially different than the second waveguide structure.	Defendant contends that this limitation is indefinite because the ’116 Patent does not describe how the two waveguide structures must be different. Nonetheless, the below references disclose different waveguide structures: Shaw discloses that different compositions of fibers can be used to cause different shifts in wavelengths. (Shaw, p. 2, ¶¶ 22, 25, 26; Fig. 3). For example, Claims 19 and 20 in Shaw’s patent application identify a variety of different types of waveguide structures that work in the IR to mid-IR range. Shaw also notes that the Fabry-Perot cavity/fiber can be formed with Bragg gratings written into the fiber. (Shaw, p. 3, ¶ 35). Because the gratings would be tailored to the specific output wavelength, they must be different if the wavelengths are different. One of skill in the art would recognize that the specific type of second fiber/waveguide will be tailored differently than the first waveguide in order to more optimally shift to higher wavelengths. The ’310 Patent discloses that different compositions of fibers can be used to cause different shifts in wavelengths because the fibers have different refractive index grating pairs, which would be different waveguide structures. (’310 Patent, Col 21:67–22:36). In the ’806 Patent, the two waveguides (Yb-doped fiber and Germanium-doped fused silica) are different from one another. The ’903 Patent discloses that fibers of different zero-dispersion wavelengths can be used to cause different Raman cascades, and thereby different shifts in wavelengths (’903 Patent, Col. 9:30–33).

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	The '903 Patent further describes that “The Raman gain fiber has the same characteristics as described above for the open-loop design.” (Col. 10:5–6). The open-loop design mentions two fibers spliced together (Col. 9:30–33). Also, the '903 Patent states that “Different fiber combinations described in the first embodiment can be used” ('903 Patent, Col. 10:27–29). Fidric discloses an embodiment wherein “the first fiber amplifier stage is a Raman amplifier and the second amplifier stage is a rare earth doped fiber amplifier.” (Fidric, p. 3, ll. 10–11). The two types of amplifiers are substantially different. The '778 Patent states that “the two cavities 331 and 332 deviate from each other slightly as they traverse the set of prisms 231 through 234.” ('778 Patent, Col. 26:44–46). Islam2002 states that “if the gain fiber cannot be made PM while retaining the other desired qualities in terms of Raman gain, then cavities such as FIGS. 19a or 19b can be used. In FIG. 19a, the cavity is formed between reflector 22 and a Sagnac loop mirror 210. The Sagnac loop mirror is made of a short length of standard or dispersion-shifted PM fiber. A Raman gain fiber 202 is placed in the middle of the cavity of the amplifier.” (Islam2002, p. 10, ¶ 125). PM fibers and non-PM fibers are considered substantially different.
2. The infrared light source of claim 1, wherein the first pump laser is selected from the group consisting of a continuous wave laser and a pulsed laser.	All lasers are either continuous wave (CW) or pulsed. Shaw specifically notes that pump laser 212 is pulsed—“The device was pumped with Continuum Mirage OPO 212 at 1.5 μm with about 8 W of peak power in a 5 ns pulse.” (Shaw, p. 4, ¶ 41). The '310 Patent incorporates by reference the system of Grubb, which uses CW lasers. ('310 Patent, Col. 21:42–49).

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	The system in the '806 Patent uses a pulsed laser (between 5–15 ns). ('806 Patent, Col. 18:20–28). In Thielen, the Continuum Mirage OPO is a pulsed laser, producing 5-ns pulses. (Thielen, p. 75). The system in Grubb is a CW system. (Grubb, p. PD3-3). The system in the '404 Patent is a CW system. ('404 Patent, Col. 2:49; Col. 8:62–9:35). The first pump (pump source 65) in the '369 Patent can be pulsed or CW. ('369 Patent, Col. 7:25–56). The '778 Patent states that “[a] diode laser injection seeder 71 contains one or more single mode diode lasers 72 (FIG. 15a) with a typical emission bandwidth of about 0.0004 nm and typical output power of a few milliwatts continuous wave.” ('778 Patent, Col. 13:51–55). Thus, the '778 Patent discloses a continuous wave diode laser. The '778 Patent further states that “the method includes Step 156 of providing the oscillator laser cavity 42 (FIG. 14a) or 77 (FIG. 14b) capable of generating the initial pump pulse 41 having a wavelength of from 750 nm to 1000 nm.” ('778 Patent, Col. 22:16–19). Thus, initial pump pulse 41 discloses a pulsed laser. Price states that “The ultrashort optical pulses 43 are generated by the optical source 12, and are coupled into the holey fiber 48 of the amplifier 14 together with the pump radiation 49 generated by the pump laser 16” (Fidric, p. 6, [0086]). Thus, the first pump laser is a pulsed laser because it generates optical pulses. Islam2002 states that “assume that a continuous wave burst of light is injected via WDM 28 from light source 26.” (Islam2002, p. 5, ¶ 75).

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3. The infrared light source of claim 1, wherein the first pump laser is selected from the group consisting of a solid state laser, a Nd:YAG laser, a Nd:YLF laser, laser diodes, a semiconductor laser, and a cladding pump fiber.	The Continuum Mirage OPO 212 of Shaw's Example 1 is a solid-state laser. The '310 Patent states that the pump sources can be semiconductor laser sources. ('310 Patent, Col. 8:24–28). The seed laser 93' in the '806 Patent is a diode laser. ('806 Patent, Col. 17:48–49, 61–65). The Continuum Mirage OPO 212 in Thielen is a solid-state laser. The system in the '404 Patent can use a Nd:YAG or Nd:YLF laser for the first pump laser. ('404 Patent, Col. 1:62–68; Col. 8:62–9:35). The pump source 65 in the '369 Patent can be a laser diode or semiconductor laser. ('369 Patent, Col. 7:25–56). The '903 Patent states that "Exemplary 1240 nm pump lasers include: (a) an 1117 nm cladding-pumped fiber laser followed by a coupler-based or grating-based Raman oscillator cavity (with gratings for 1117 nm, 1175 nm and 1240 nm); (b) an optically-pumped semiconductor laser; or (c) a chromium-doped forestries laser" ('903 Patent, Col. 9:38–43). Thus, the '903 Patent discloses a semiconductor laser and a cladding-pumped fiber laser. Fidric states that "[t]he Raman amplifier is pumped by pump energy generated by pump source 1006, which may be, e. g., a laser diode." (Fidric, p. 12, ll. 2–4). Fidric further states that "[p]ump energy at a wavelength of 980 nm is generated by pump source 1104, which may be a laser diode" (Fidric, p. 13, ll. 7–8). Fidric further states that "[a]lternatively, the single pump source may be provided as two high-power diodes which provide an output signal having a wavelength typically of about 1470 nm, or by using another broadband type source with broad or multiple wavelength peaks." (Fidric, p. 4, ll. 15–18). The disclosure of two high-power diodes anticipates laser diodes of the claim.

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	The ’778 Patent states that “[w]hen fine wavelength control is required, the pump laser cavity 330 is injection seeded using one or more of the diode lasers 350 (FIG. 24). Emission or seed light 351 from the laser diodes 350 is collimated using lenses 225 and is coupled into single mode fibers 352.” (’778 Patent, Col. 28:5–9). The ’778 Patent discloses that the first pump laser is a laser diode. Price discloses an optical source 12, which is embodied as a “fiber laser having as a gain medium an optical fiber 20.” (p. 4, [0062]). Also, <i>see</i> Fig. 2, which shows a schematic diagram of the optical source 12. Price states that “pump light at 975 nm is coupled into the gain medium fiber 20. The pump light is generated by a diode laser (not shown).” (Price, p. 4, [0062]). Thus, the first pump laser comprises a laser diode, i.e., one of the elements in the claimed list of elements. As stated in the ’636 Patent, “[t]he sources are typically semiconductor lasers and are coupled together, as by a coupler line segment 21.” (’636 Patent, Col. 3:40–41). Islam2002 states that “[t]he light source 26 can be any suitable source of optical energy. Because the Raman effect relies upon intense optical energy, high power semiconductor or cladding-pumped fiber lasers are presently preferred.” (Islam2002, p. 5, ¶ 73). Or in an alternative embodiment: “[t]he cladding-pumped fiber generates a pumping light which subsequently pumps the fiber loop 30.” (Islam2002, p. 9, ¶ 118). The signal laser 214 of Shaw’s Example 1 is a laser diode. (Shaw, p. 4, ¶ 41). The ’310 Patent states that the pump sources can be semiconductor laser sources. (’310 Patent, Col. 8:24–28). The pump laser in the ’806 Patent is a high-power semiconductor diode, which would fall within either the laser diode or semiconductor laser designation of the claim. (’806 Patent, Col. 17:67–18:1).
4. The infrared light source of claim 1, wherein the second pump laser is selected from the group consisting of a solid state laser, a Nd:YAG laser, a Nd:YLF laser, laser diodes, a semiconductor laser, and a cladding pump fiber.	

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	The signal laser in Thielen is a laser diode. (Thielen, p. 75) The system in the ’404 Patent can use a laser diode for the second pump laser. (’404 Patent, Col. 1:49–61). The second pump laser in the ’369 Patent (laser diode 61). (’369 Patent, Col. 10:16–20). The ’903 Patent discloses cladding-pumped fiber in Example 5: “To illustrate the cascaded Raman amplification to reach the 1430-1530 nm range of the low-loss window, consider pumping with a commercially available cladding-pumped fiber laser, which operates around 1060 to 1140 nm” (’903 Patent, Col. 7:64–67). Fidric states that “[t]he Raman amplifier is pumped by pump energy generated by pump source 1006, which may be, e. g., a laser diode.” (Fidric, p. 12, ll. 2–4). Fidric further states that “[p]ump energy at a wavelength of 980 nm is generated by pump source 1104, which may be a laser diode” (Fidric, p. 13, ll. 7–8). Fidric further states that “[a]lternatively, the single pump source may be provided as two high-power diodes which provide an output signal having a wavelength typically of about 1470 nm, or by using another broadband type source with broad or multiple wavelength peaks.” (Fidric, p. 4, ll. 15–18). The disclosure of two high-power diodes anticipates laser diodes of the claim. The ’778 Patent states that “[w]hen fine wavelength control is required, the pump laser cavity 330 is injection seeded using one or more of the diode lasers 350 (FIG. 24). Emission or seed light 351 from the laser diodes 350 is collimated using lenses 225 and is coupled into single mode fibers 352.” (’778 Patent, Col. 28:5–9). The ’778 Patent discloses that the second pump laser is a laser diode. Price states that “[t]he MOPA may conveniently be replaced with a conventional single-mode semiconductor laser diode operating somewhere in the range 910 nm-985 nm.” (Price, p. 5, [0070]). Price further states that “[t]he pump laser might also be a

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	diode pumped solid state laser, or a broad-stripe (multimode) laser diode operating at a suitable pump wavelength.” (Price, p. 5, [0070]). Thus, Price discloses a solid-state laser and a laser diode, both of which are disclosed in Claim 4. As stated in the ’636 Patent, “[t]he sources are typically semiconductor lasers and are coupled together, as by a coupler line segment 21.” (’636 Patent, Col. 3:40–41). Islam2002 states that “[a] high-powered diode-array-cladding-pumped fiber laser 25 operating around 1.1 μm pumps the Sagnac Raman laser.” (p. 8, ¶ 97). “[I]t will be understood that the principles of the invention can be extended to still further embodiments.” (Islam2002, p. 12, ¶ 140).
9. The infrared light source of claim 1, wherein the longer optical wavelength comprises a pulsed optical signal having a pulse repetition rate in the range of two (2) hertz to one hundred (100) megahertz.	The Continuum Mirage OPO of Shaw operates at 10 Hz. (<i>See</i> Thielen, p. 75). The repetition rate of the laser in the ’806 Patent is 10 kHz. (’806 Patent, Col. 17:55). The Continuum Mirage OPO of Thielen operates at 10 Hz. (Thielen, p. 75). The ’778 Patent states that the output of the system using this technique can be 10 Hz. (’778 Patent, Col. 29:34–36). Price states that “The average output power of the optical source is 3 mW at a pulse repetition rate of 54 MHz, indicating a pulse energy of 60 pJ,” which lies in the claimed range of 2 MHz to 100 MHz. (Price, p. 5, [0069]). The ’462 Patent describes a variety of pulsed lasers at repetition rates in the 1–10 kHz range. (’462 Patent, Figs. 8–15, Col. 2:10–61, 15:35–38). The ’869 Patent describes a Nd:YAG laser that produces pulses of light at 10 Hz. (’869 Patent, Col. 5:19–22). The ’779 Patent describes a laser that produces light at a repetition rate of 80 MHz. (’779 Patent, Col. 1:52–57, 2:40–44).

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	The ’034 Patent describes a 1.44 μm Nd:YAG pulsed laser at a repetition rate of 30–100 Hz. (’034 Patent, Col. 5:24–28). Smart describes a variety of laser sources that were well known in the art that produce light in the range of 1.3–1.5 μm at repetition rates in the 20 kHz range. (Smart, ¶¶ 122, 129). The ’877 Patent describes a 1.5 μm fiber laser at a repetition rate of 50 MHz. (’877 Patent, Col. 6:35–45).
12. The infrared light source of claim 1, wherein the one or more combiners are selected from the group consisting of a wavelength division multiplexer and a power coupler.	The 2x2 coupler 216 of Shaw’s Example 1 is a power coupler. The ’310 Patent uses a wavelength division multiplexer (WDM) 18 to combine laser light from different laser sources ($L_1, L_2, \dots, L_n$). (’310 Patent, Col. 9:12–14). The 50/50 fused silica coupler in Thielen is a power coupler. The coupler in Grubb is a wavelength division multiplexer (WDM). (Grubb, Figure 1). The coupler in the ’404 Patent is a wavelength division multiplexer (WDM). (’404 Patent, Col. 6:16–31). The ’903 Patent states in relation to the first embodiment (Fig. 9): “the input port and output port each comprises a WDM coupler which transmits at least at a wavelength between about 1240 nm and 1425 nm.” (’903 Patent, Col. 10:16–19). The ’903 Patent further states in relation to Fig. 12 that: “It is preferred that both the dividing means 230 and the combining means 260 are WDM couplers.” (’903 Patent, Col. 11:49–51). Fidric discloses wavelength division multiplexers on several occasions throughout the description and figures. See citations above. A plurality of the embodiments of Fidric utilize wavelength division multiplexers.

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	The fiber splice 354 in the '778 Patent is a power coupler. Price discloses the use of a wavelength division multiplexer (labelled 'WDM' in Fig. 2) in the context of the optical source 12. Using a WDM as an alternative to the dichroic mirror (element 54) is an obvious alternative in view of the teaching of Price alone. As stated in the '636 Patent, "[t]he source 11 can comprise a modulated laser or light-emitting diode. Preferably it is an array of lasers or diodes for providing a plurality of modulated wavelength distinct optical signals for a wavelength division multiplexed (WDM) optical system." ('636 Patent, Col. 3:22–26). The '636 Patent describes in Example 1 that "the first-order pump has wavelengths ranging from 1430-1475 nm and is generated by sets of polarization multiplexed diodes." ('636 Patent, Col. 4:11–13). In Islam2002, the combiners are wavelength division multiplexers. "The optical signal to be amplified, injected through WDM coupler 42." (Islam2002, p. 5, ¶ 73). "[T]he two WDM couplers 42 and 44 can be designed for any desired signal wavelengths (not necessarily between 1300 nm and 1310 nm)." (Islam2002, p. 5, ¶ 73). The fiber 210 of Shaw's Example 1 is a chalcogenide fiber (As-Se). (Shaw, p. 4, ¶ 41). In the '310 Patent, Raman fiber laser 63A is a single-mode fiber. ('310 Patent, Col. 22:1–3). The fiber in Thielen is a chalcogenide fiber (As-Se). (Thielen, pp. 74–75).
13. The infrared light source of claim 1, wherein the first waveguide structure is selected from the group consisting of a dispersion compensating fiber, a dispersion shifted fiber, a single mode fiber, a chalcogenide fiber, and a fused silica optical fiber.	

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	The fiber amplifier in the '404 Patent is a fused silica fiber. ('404 Patent, Col. 2:38–41). The '903 Patent discloses a single-mode fiber: “In this open-loop configuration, the fiber must have a cut-off wavelength below 1240 nm to be single-mode (spatial) over all wavelengths of the Raman cascade. Three choices of the fiber are preferred in this configuration. First, FIG. 9a, a standard dispersion fiber with a zero-dispersion wavelength at about 1310 nm. Second, FIG. 9b, two fibers spliced together with one fiber having a zero-dispersion wavelength at about 1310 nm (first cascade) and the other at 1390 nm (second cascade).” ('903 Patent, Col. 9:27–33). Fidric states that “[a] still further improvement can be obtained by using a dispersion compensating fiber for the Raman gain fiber.” (Fidric, p. 9, ll. 18–19). Thus, Fidric discloses one of the examples in the claim. Price states that “[f]urthermore, the tailoring of the fiber to achieve the desired characteristics is not limited to the use of holey fibers” (Price, p. 9, [0124]) and “fibers fabricated from materials other than silica may be suitable for particular applications. It is also possible to envisage such fibers produced in glasses other than silica based glasses. Such compound glass types include...chalcogenide glasses.” (Price, p. 9, [0125]). Thus, Price discloses using a chalcogenide fiber instead of a holey fiber. As stated in the '636 Patent, “[t]he transmission fiber is composed of 80 km of nonzero-dispersion-shifted fiber with an effective area of approximately 55 square microns.” (“'636 Patent, Col. 4:20–23). In one embodiment in Islam2002, a single mode fiber is disclosed: “[t]he gain fiber of the Sagnac mirror is single mode not only at Raman order wavelengths but also at the pump wavelength.” (Islam2002, p. 9, ¶ 116).

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	In another embodiment, a dispersion shifted fiber is disclosed: “[t]he Sagnac loop mirror is made of a short length of standard or dispersion-shifted PM fiber.” (Islam2002, p. 10, ¶ 125).
14. The infrared light source of claim 1, wherein at least a portion of the first waveguide structure is selected from the group consisting of an optical fiber, a hollow tube waveguide, an air core waveguide, and a planar waveguide.	The fiber 210 of Shaw’s Example 1 is an optical fiber (specifically, a chalcogenide fiber (As-Se)). (Shaw, p. 4, ¶ 41).
	In the ’310 Patent, Raman fiber laser 63A is a single-mode fiber. (’310 Patent, Col. 22:1–3).
	The Yb-doped fiber amplifier 90’ in the ’806 Patent is an optical fiber.
	The fiber in Thielen is an optical fiber (specifically, a chalcogenide fiber (As-Se)). (Thielen, p. 74).
	The germanosilicate fiber in Grubb is an optical fiber. (Grubb, p. PD3-2).
	The fiber amplifier in the ’404 Patent is an optical fiber. (’404 Patent, Col. 2:38–41).
	The fiber amplifier in the ’369 Patent is an optical fiber. (’369 Patent, Col. 10:13–16).
	The ’903 Patent discloses that the first waveguide structure is an optical fiber: “In this open-loop configuration, the fiber must have a cut-off wavelength below 1240 nm to be single-mode (spatial) over all wavelengths of the Raman cascade. Three choices of the fiber are preferred in this configuration. First, FIG. 9a, a standard dispersion fiber with a zero-dispersion wavelength at about 1310 nm. Second, FIG. 9b, two fibers spliced together with one fiber having a zero-dispersion wavelength at about 1310 nm (first cascade) and the other at 1390 nm (second cascade).” (’903 Patent, Col. 9:27–33).

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	Fidric states that “[a] still further improvement can be obtained by using a dispersion compensating fiber for the Raman gain fiber.” (Fidric, p. 9, ll. 18–19). A dispersion compensating fiber is an optical fiber. Price discloses a holey fiber, also known as a microstructured fiber (Price, p. 4, [0058]–[0059]). A holey fiber is disclosed throughout the description. (See, e.g., Price, paragraphs [0070]–[0079]). A holey fiber is a type of optical fiber and thus anticipates at least one of the elements in the list of claimed elements. The first waveguide structure in Islam2002 is an optical fiber.
16. The infrared light source of claim 1, wherein at least a portion of the second waveguide structure is selected from the group consisting of an optical fiber, a hollow tube waveguide, an air core waveguide, and a planar waveguide.	In Shaw’s Example 1, he describes how additional fibers can be cascaded, and those would be optical fibers. “A fiber Raman laser in its simplest form consists of a gain medium in a Fabry-Perot cavity for wavelength sensitive feedback. The Fabry-Perot cavity can be formed by reflecting means such as mirrors or fiber Bragg gratings written into the fiber.” (Shaw, p. 3, ¶ 35). “The latter embodiment involves cascading several Fabry-Perot cavities such that the output Stokes from one cavity is trapped in the next Fabry Perot cavity that generates and amplifies a second Stokes at longer wavelength. With this process, the initial pump beam may be shifted up in wavelength through several Stokes shifts to generate a high power beam at wavelengths corresponding to multiples of the Raman shift.” (Shaw, p. 3, ¶ 36). The ’310 Patent stated that the second Raman fiber laser 63B is like the first 63A, which is a single-mode fiber (’310 Patent, Col. 22:1–3, 10–13). The Germanium-doped fused silica fiber 901 in the ’806 Patent is an optical fiber. The ’903 Patent discloses that the second waveguide structure is an optical fiber: “Three choices of the fiber are preferred in this configuration. First, FIG. 9a, a standard dispersion fiber with a zero-dispersion wavelength at about 1310 nm. Second, FIG. 9b, two fibers spliced together with one fiber having a zero-dispersion

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	wavelength at about 1310 nm (first cascade) and the other at 1390 nm (second cascade).” (’903 Patent, Col. 9:27–33). Fidric states that “[t]he next stage through which the optical signal passes includes an erbium/ytterbium (Er/Yb) doped fiber gain medium 1223.” (Fidric, p. 15, ll. 18–19). An Er/Yb doped fiber gain medium is a type of optical fiber. The second waveguide structure in Islam2002 is an optical fiber.
19. The infrared light source of claim 1, wherein the longer optical wavelength comprises a wavelength of approximately 1.7 microns or more.	Shaw states how his technique can create Raman shifts up to 15 μm. (Shaw, p. 2, ¶ 20). Shaw’s Example 2 shows how wavelengths of at least 6.2 μm can be obtained using his technique. (Shaw, p. 4, ¶ 42). Table 1 of the ’903 Patent provides various Raman orders when pumping between 1060 and 1140 nm (separation of 13.2 THz between orders). (’903 Patent, Col. 8:5–42). The last entry in Table 1 lists a wavelength of 1756.87 nm, which is longer than 1.7 microns. The ’778 Patent states that “in response to the medium 112 in the cell 111 shifts the wavelength of the initial laser pulse 41 to the second Stokes wavelength, within the range 48 of from 2 to 6 microns.” (’778 Patent, Col. 15:57–60). The ’778 Patent further states that “FIG. 14a is a schematic diagram of an embodiment of apparatus which outputs a double Raman shifted laser pulse at a fixed wavelength within a nominally 2 to 6 micron range according to the present invention.” (’778 Patent, Col. 5:27–30). The ’778 Patent further states that “[t]he second Stokes pulse 47 is nominally at any wavelength within an output range 48 (FIG. 14a) of 2 to 6 microns.” (’778 Patent, Col. 8:15–17). The ’778 Patent further states that “[i]n the example shown in FIG. 5, a point 54 represents the index of refraction of the second Stokes output pulse 47 having a wavelength of 3.35 microns.” (’778 Patent, Col. 10:15–17). Wavelengths of 2 to 6 or 3.35 microns fall within the claimed range.

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<i>Claim Term</i>	<i>References</i>
	Price states that “[t]he maximum wavelength shift of the Raman soliton increases steadily with the length of fiber used, so, in a silica fiber, the maximum obtainable wavelength will, in principle, have an upper bound set by the absorption of silica, at around 2.3 μm.” (Price, p. 7, [0093]). The disclosed wavelength of 2.3 μm lies in the claimed range of 1.7 μm or more. Islam2002 states that “[f]inally, by varying the pump wavelength or by using cascaded orders of Raman gain, the gain can be provided over the entire telecommunications window between 1.3 μm and 1.6 μm.” (Islam2002, p. 5, ¶ 70).
20. The infrared light source of claim 1, wherein the longer optical wavelength comprises a wavelength in the range of two (2) microns to ten (10) microns.	Shaw states how his technique can create Raman shifts up to 15 μm. (Shaw, p. 2, ¶ 20). Shaw’s Example 2 shows how wavelengths of at least 6.2 μm can be obtained using his technique. (Shaw, p. 4, ¶ 42). The ’778 Patent states that “in response to the medium 112 in the cell 111 shifts the wavelength of the initial laser pulse 41 to the second Stokes wavelength, within the range 48 of from 2 to 6 microns.” (’778 Patent, Col. 15:57–60). The ’778 Patent further states that “FIG. 14a is a schematic diagram of an embodiment of apparatus which outputs a double Raman shifted laser pulse at a fixed wavelength within a nominally 2 to 6 micron range according to the present invention.” (’778 Patent, Col. 5:27–30). The ’778 Patent further states that “[t]he second Stokes pulse 47 is nominally at any wavelength within an output range 48 (FIG. 14a) of 2 to 6 microns.” (’778 Patent, Col. 8:15–17). The ’778 Patent further states that “[i]n the example shown in FIG. 5, a point 54 represents the index of refraction of the second Stokes output pulse 47 having a wavelength of 3.35 microns.” (’778 Patent, Col. 10:15–17). Wavelengths of 2 to 6 or 3.35 microns fall within the claimed range. Price states that “[t]he maximum wavelength shift of the Raman soliton increases steadily with the length of fiber used, so, in a silica fiber, the maximum obtainable wavelength will, in principle, have an upper bound set by the absorption of silica, at

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	around 2.3 μm.” (Price, p. 7, [0093]). The disclosed wavelength of 2.3 μm lies in the claimed range of 2 μm to 10 μm.
22. The infrared light source of claim 1, further comprising a wavelength separator coupled to the wavelength shifter and capable of transmitting at least a portion of a selected wavelength from the wavelength shifter.	In Shaw’s Example 1, he uses a wavelength separator 218 after the Raman amplifier to remove the unwanted light and only transmit the shifted light. (Shaw, p. 4, ¶ 41). The ’806 Patent uses a filter 903 after the final output (which can be a diffraction grating or interference filter) to narrow the bandwidth and reject spurious wavelengths. (’806 Patent, Col. 18:11–13). In Thielen, they use a wavelength separator after the Raman amplifier to remove the unwanted light and only transmit the shifted light. “The other end of the As-Se fiber was fed into a Jarrel-Ash $\frac{1}{4}$-meter monochromator to spectrally separate the pump from the amplified signal.” (Thielen, p. 75). The ’903 Patent discloses a retro-reflector (element 45) coupled to the wavelength shifter, Fig. 9. The ’903 Patent further states that “[t]he retro-reflector is preferably a dichroic mirror or a 1240 nm grating” (’903 Patent, Col. 9:45–46). Additionally, Figs. 10–11 of the ’903 Patent show a coupler (element 90) capable of transmitting at least a portion of a selected wavelength from the wavelength shifter. The ’903 Patent further states that: “The optical coupler 90 is nominally 50:50 at least for the optical signal having a wavelength between about 1240 nm and 1430 nm. The coupling means 85 is a WDM coupler which transmits at least at a wavelength between about 1300 nm and 1430 nm” (’903 Patent, Col. 10:12–14). Fidric states that “[m]oreover, in the preferred embodiment, the grating 1142 is made only partially (e. g., 80%) reflective at the 1470 nm wavelength, such that some of the 1470 nm optical energy reaches WDM 1144.” (Fidric, p. 14, ll. 6–8). Thereby, at least

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	a portion of a selected wavelength (here, 1470 nm) is transmitted from the wavelength shifter. Price states that “[t]he final output of the amplifier, as the second wavelength, leaves the holey fiber 48 through the second end 70, and is transmitted through the dichroic mirror 66.” (Price, p. 8, [0106]). The dichroic mirror is a wavelength separator coupled to the wavelength shifter. Islam2002 states that “[r]eflector 24 is a Sagnac interferometer including a dichroic coupler 32b and a fiber loop. Dichroic coupler 32b is used to provide frequency selectivity. The dichroic coupler provides nominally 50:50 coupling over the cascade Raman order wavelengths.” (Islam2002, p. 7, ¶ 90).
23. The infrared light source of claim 22, wherein the wavelength separator is selected from the group consisting of a demultiplexer, one or more partially transmissive gratings, one or more partially transmitting mirrors, one or more Fabry	In Shaw's Example 1, he uses a Jarrel-Ash ¼-meter monochromator 218 to separate the wavelengths, which contains dielectric gratings. (Shaw, p. 4, ¶ 41). The '806 Patent discloses a filter 903, such as a diffraction grating that is used to separate spurious wavelength. ('806 Patent, Col. 18:11–13).

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Perot filters and one or more dielectric gratings.	In Thielen, they use a Jarrel-Ash ¼-meter monochromator to separate the wavelengths, which contains dielectric gratings. (Thielen, p. 75). The '903 Patent states that "The retro-reflector is preferably a dichroic mirror or a 1240 nm grating," which is a partially transmitting mirror. ('903 Patent, Col. 9:45–46). Fidric discloses a partially transmissive grating. (Fidric, p. 14, ll. 6–8). Fidric further discloses in Claim 8: "wherein a reflector of the reflector pair is partially reflective and a portion of optical energy within the peak wavelength range exits the third stage and is coupled to the first amplifier stage." (Fidric, p. 18). Price states that "[t]he final output of the amplifier, as the second wavelength, leaves the holey fiber 48 through the second end 70, and is transmitted through the dichroic mirror 66." (Price, p. 8, [0106]). A dichroic mirror is "one or more partially transmitting mirrors." Islam2002 states that "FIG. 7a depicts a fifth embodiment of the invention which employs a Fabry-Perot wavelength filter 54 to narrowly select the Raman pump orders." (Islam2002, p. 7, ¶ 93). "Thus a single Fabry-Perot interferometer can be used to replace the multiple gratings 50 and 52 of the FIG. 5 embodiment, because the transmission function is a periodic function of frequency." (Islam2002, p. 7, ¶ 94).
24. The infrared light source of claim 1, further comprising at least a third waveguide structure coupled to the wavelength shifter, wherein a coupling loss between the third waveguide structure and the wavelength shifter comprises no more than five (5) decibels.	One of ordinary skill in the art would recognize that fibers are routinely coupled together with losses less than 5 decibels. Shaw describes how his process can be used in sequence to upshift an initial pump beam multiple times using multiple fibers: "The latter embodiment involves cascading <i>several</i> Fabry-Perot cavities such that the output Stokes from one cavity is trapped in the next Fabry Perot cavity that generates and amplifies a second Stokes at longer wavelength. With this process, the initial pump beam may be shifted up in wavelength

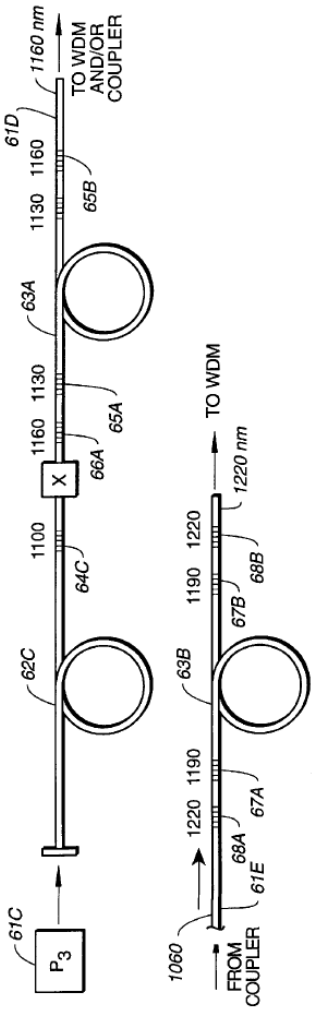
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	through <i>several</i> Stokes shifts to generate a high power beam at wavelengths corresponding to multiples of the Raman shift.” (Shaw, p. 3, ¶ 36) (emphasis added). Shaw, therefore, discloses that a third waveguide structure can be coupled to the wavelength shifter that has a coupling loss of no more than 5 decibels. To the extent that Plaintiff contends that any fiber coupled to the wavelength shifter satisfies this claim limitation, the coupling of fibers to the output of fiber lasers is a routine and obvious combination. See, e.g., Shaw, Figure 6, elements 132, 134, and 138: FIG. 6 In the '310 Patent, the output of the second waveguide structure (63B) is sent to a WDM, which is a type of waveguide structure within the meaning of the claim. ('310 Patent, Figure 22):

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	 FIG. 22 Fidric further discloses a three-stage amplifier, i.e., comprising a third waveguide structure—“[i]n addition the inventive multistage amplifier can be used in combination with other amplifiers. For example, the disclosed Raman/erbium-doped amplifier can be used as the second and third stage of a three stage amplifier.” (Fidric, p. 16, ll. 7–9). Fidric further states that “[a]mplifier 14 is comprised of a cladded optical fiber which may be, for example, a germano-silica fiber having a core diameter typically in the range of about 2, um–5 pm and having an insertion loss characteristic not greater than 0.6 decibels per kilometer (db/km) at a wavelength of about 1470 nm.” (p. 6, l. 32–p. 7, l. 2). Thus, it would be obvious to ensure that a coupling loss between the third waveguide structure and the wavelength shifter comprises no more than five (5) decibels in view of the teaching by Fidric alone.