

Photodigm, Inc.



Inventor 1 *Sarvotham Bhandarkar* 9/11/03 Sarvotham Bhandarkar
Inventor 2 *Jaime Castilleja* 9/11/03 Jaime Castilleja
Witness *John E. Spencer* 9/11/03 John Spencer

**GSE Laser enabled
LX4 CWDM Mux**

9/11/2003

1

Value Proposition

Inventor 1	<u>Sarvotham Bhandarkar</u> 9/11/03	Sarvotham Bhandarkar
Inventor 2	<u>Jaime Castilleja</u> 9/11/03	Jaime Castilleja
Witness	<u>John E. Spencer</u> 9/11/03	John Spencer

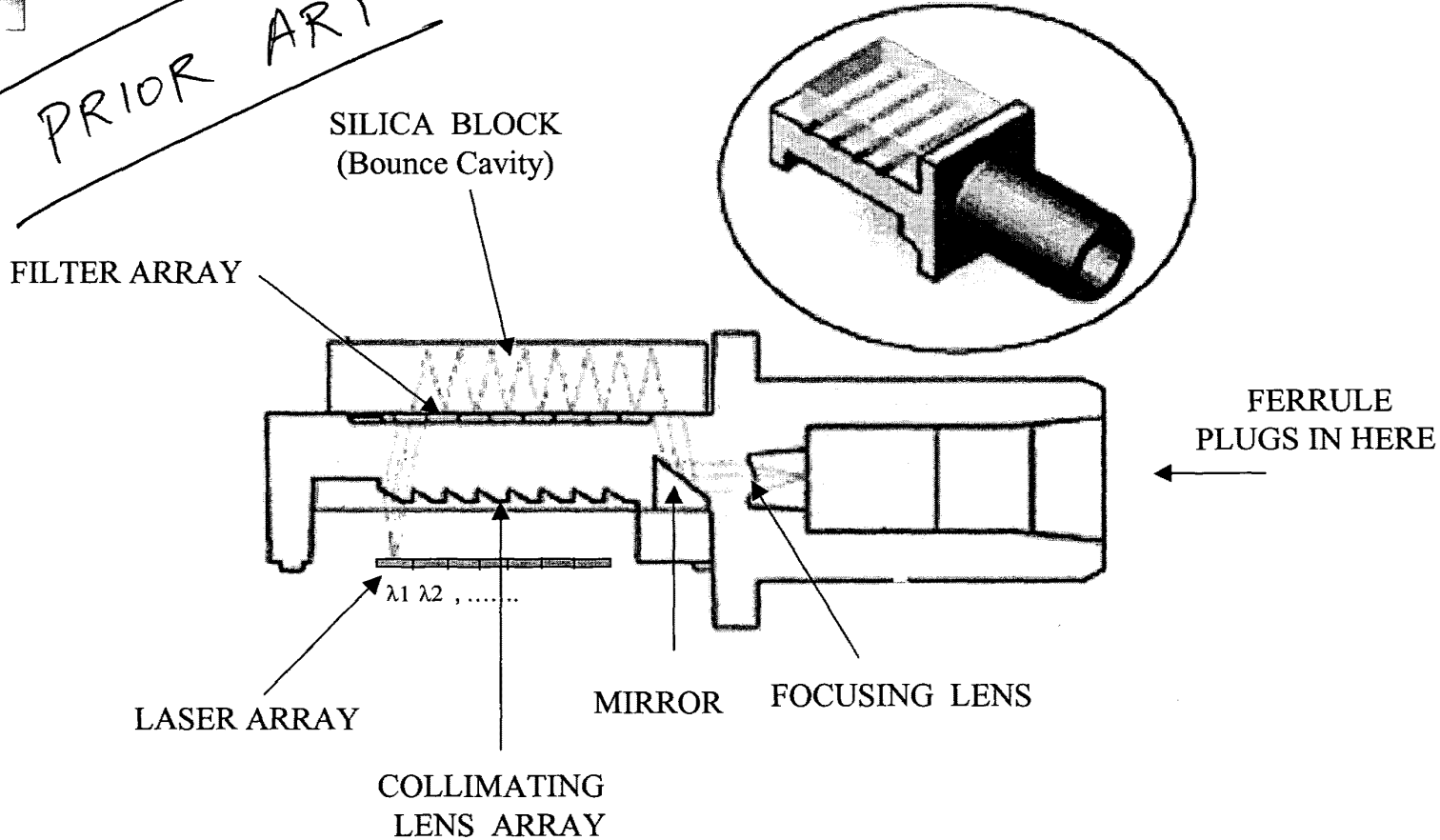
Using the unique characteristics of the GSE laser ,

- Existing LX4 Mux designs (e.g. Aduro/Blaze, Molex, Pine Photonics) can be built at lower cost and higher fiber coupling efficiencies
- A Photodigm-proprietary Mux can be built that considerably simplifies the package and offers cost advantages over current designs

Aduro LX4 Mux - Schematic

Inventor 1 Sarvatham Bhandarkar 9/11/03 Sarvatham Bhandarkar
 Inventor 2 Jaime Castilleja 9/11/03 Jaime Castilleja
 Witness JES 9/11/03 John Spencer

PRIOR ART



NOTE : SCHEMATIC ADAPTED FROM BLAZE / ADURO WEBSITE

Aduro LX4 Mux – Principle of Operation

Inventor 1 Sarvotham Bhandarkar 9/11/03 Sarvotham Bhandarkar

Inventor 2 Jaime Castilleja 9/11/03 Jaime Castilleja

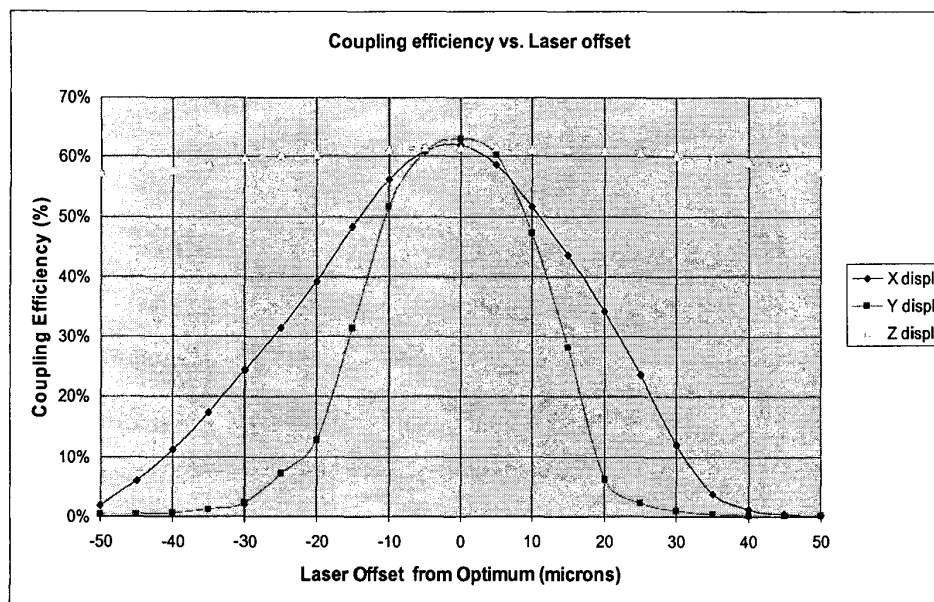
Witness JES 9/11/03 John Spencer

- The collimating lens array collimates the light from each laser and injects it at a precise angle into the bounce cavity
- Each filter allows one λ to pass through but reflects all other λ 's
- At subsequent filter locations an additional λ is muxed, until all λ 's are muxed into the single collimated beam
- The final muxed beam is folded by a mirror and focused into the end of MM fiber ferrule
- The Mux can be used as a Demux with photodiodes replacing the lasers.

GSE Coupling efficiency

Inventor 1 Sarvotham Bhandarkar 9/11/03 Sarvotham Bhandarkar
 Inventor 2 Jaime Castilleja 9/11/03 Jaime Castilleja
 Witness JS 9/11/03 John Spencer

- Aduro LX4 mux with GSE Laser, into MM SC ferrule
 - GSE laser is placed at first lens position (adjacent to ferrule) w/o filter
 - 15 um outcoupler
 - Experimental data using Newport Autoalign station



- 63% max. coupling efficiency into MM fiber (first channel w/o filter)
- Relatively insensitive to offsets (10% loss @ 10um offset)
- Last channel coupling can be upto 35% lower than first channel (due to filters & multiple reflections)

DFB coupling efficiencies

Inventor 1 Sarvotham Bhandarkar 9/11/03 Sarvotham Bhandarkar
 Inventor 2 Jaime Castilleja 9/11/03 Jaime Castilleja
 Witness JES 2/14/03 John Spencer

- Aduro LX4 mux with DFB Lasers, into MM SC ferrule
 - Modeling data from Zemax
 - DFB is placed at optimal position at focal length of lens

Parameter	Mitsubishi	Luxnet	Demeter	Luminent
Wavelength (nm)	1310	1310	1310	1300
Divergence x-dir (deg) $1/e^2$	21	15	15	22
Divergence y-dir (deg) $1/e^2$	24	28	40	26
Coupling Eff. into MM Fiber	19%	23%	16%	17%

**23% max. coupling
efficiency into MM
fiber**

GSE vs. DFB (with Aduro Mux)

Inventor 1 Sarvotham Bhandarkar 9/11/03 Sarvotham Bhandarkar
Inventor 2 Jaime Castilleja 9/11/03 Jaime Castilleja
Witness JBS 9/11/03 John Spencer

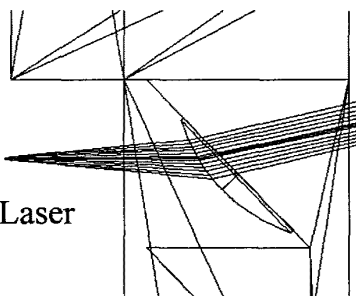
- The lower divergence of the GSE beam allows better coupling into the Mux.
- The Mux is better suited to a surface emitting laser.
- DFB's need additional packaging (e.g., v-groove and lens) to properly align and couple into the Mux)

•Source: GSE Laser

•Divergence:

•x-dir: 3 deg

•y-dir: 11 deg

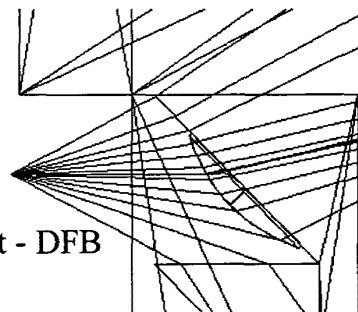


•Source: Luxnet - DFB

•Divergence:

•x-dir: 15 deg

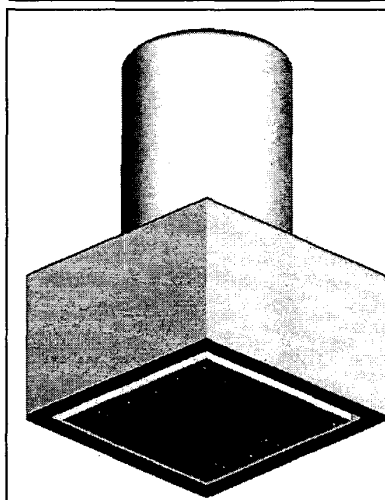
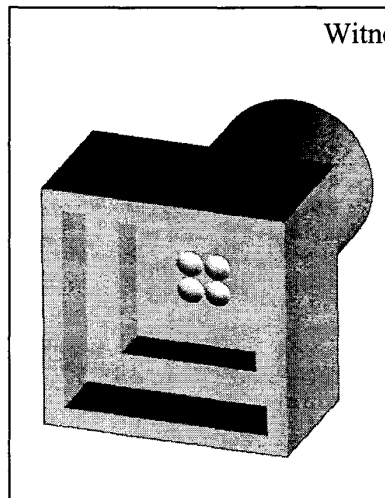
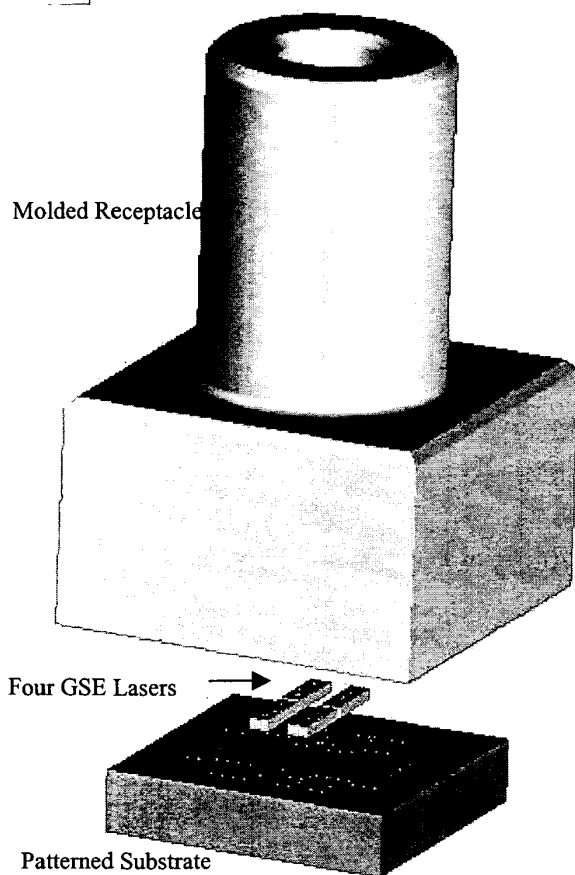
•y-dir: 28 deg



The collimating lens is unable to capture the entire DFB beam even at 750 um spacing

Photodigm Mux

Inventor 1 Sarvatham Bhandarkar 9/11/03
 Inventor 2 Jaime Castilleja 9/11/03
 Witness JES 9/11/03 John Spencer



Concept

- 2x2 array of GSE lasers
- 2x2 array of collimating lens
- Integrated focusing lens

Product

- Four λ mux with conventional GSE
- Eight λ mux with cross-grating GSE
- Form factor compatible with single laser TOSA's (4.5 mm² footprint)
- Each laser is monitored by a PD

Key Enablers

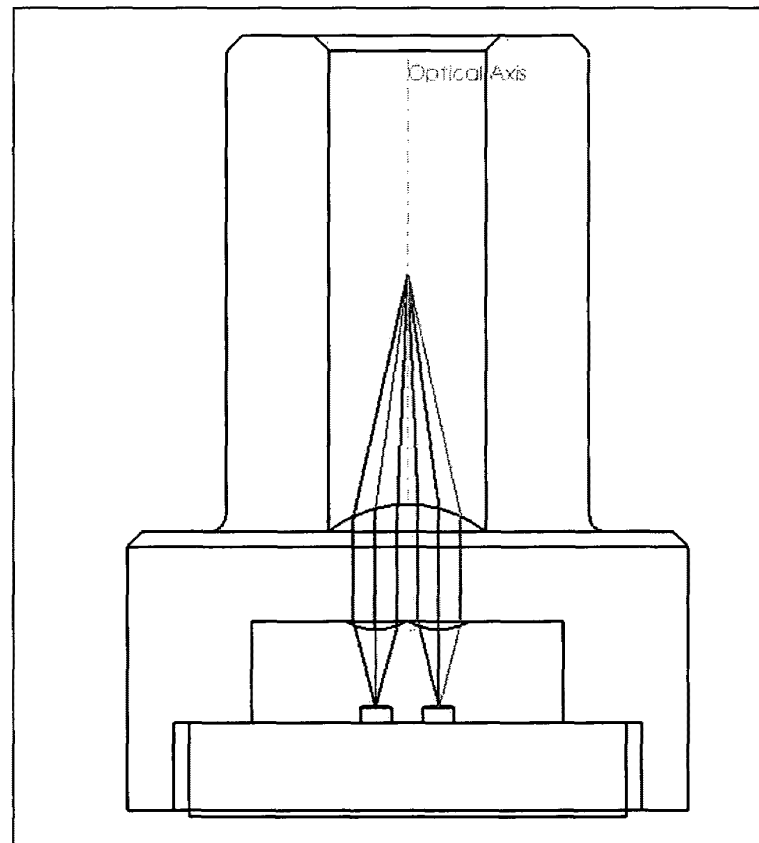
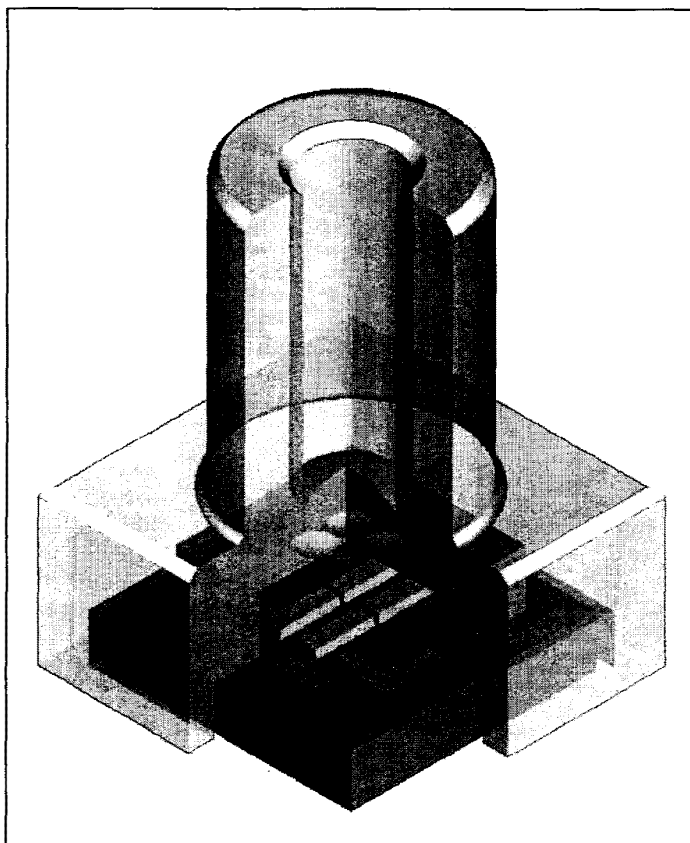
- Surface emission
- Low divergence
- Backside emission / Integrated PD

Photodigm Mux – Cutaway view

Inventor 1 Sarvotham Bhandarkar 9/11/03 Sarvotham Bhandarkar

Inventor 2 Jaime Castilleja 9/11/03 Jaime Castilleja

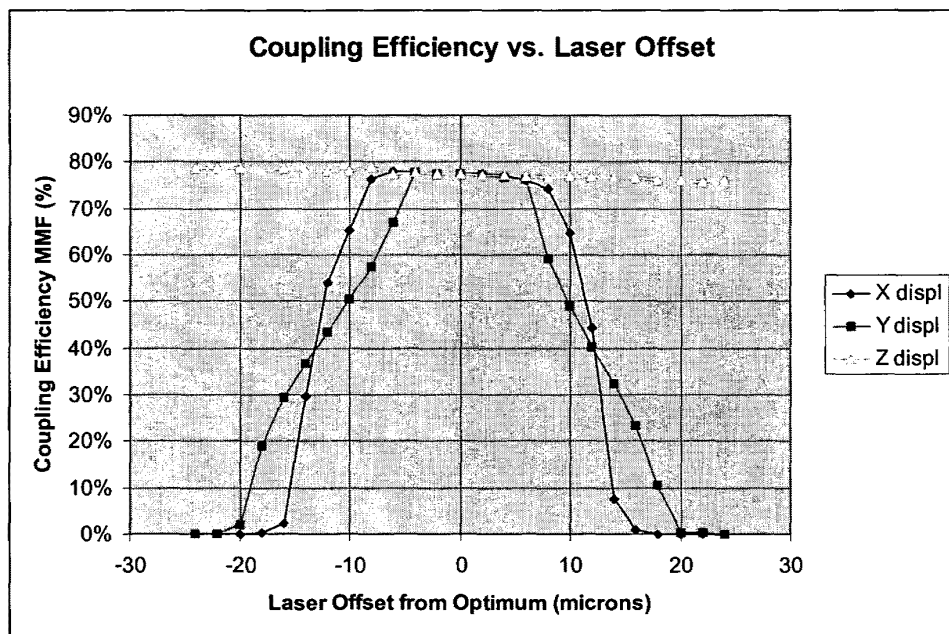
Witness JES 9/11/03 John Spencer



Photodigm Mux – Coupling Efficiency

Inventor 1 Sarvotham Bhandarkar 9/11/03
 Inventor 2 Jaime Castilleja 9/11/03
 Witness JES 9/11/03 John Spencer

- Photodigm Mux, with GSE coupled into MM fiber
 - Theoretical data using Zemax
 - 15 micron out coupler



- 77% max. coupling efficiency into MM fiber
- Relatively insensitive to offsets (<10% loss @ +/- 5 μ m offset)

Photodigm Mux - Advantages

Inventor 1 *Sarvotham Bhandarkar* 9/11/03 Sarvotham Bhandarkar
Inventor 2 *Jaime Castilleja* 9/11/03 Jaime Castilleja
Witness *JS* 9/11/03 John Spencer

- Eliminates multiple bounce cavity
 - Less noise / feedback between lasers
 - Eliminates loss from multiple reflections
- Eliminates filter
 - Eliminates loss due to inefficiencies in the filter
 - Eliminates cost of filter
- Simpler design, easier to mold -> lower cost

Photodigm Mux – Monitor Photodiode

Inventor 1

Sarvotham Bhandarkar 9/11/03

Sarvotham Bhandarkar

Inventor 2

Jaime Castilleja 9/11/03

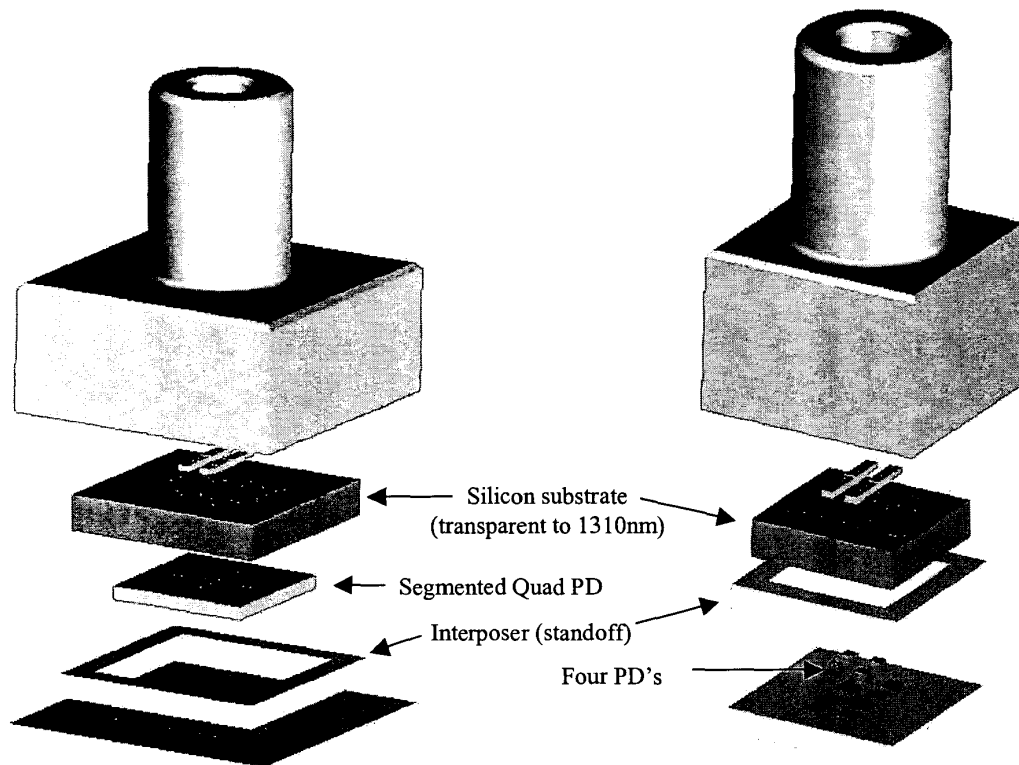
Jaime Castilleja

Witness

John Spencer 9/11/03

John Spencer

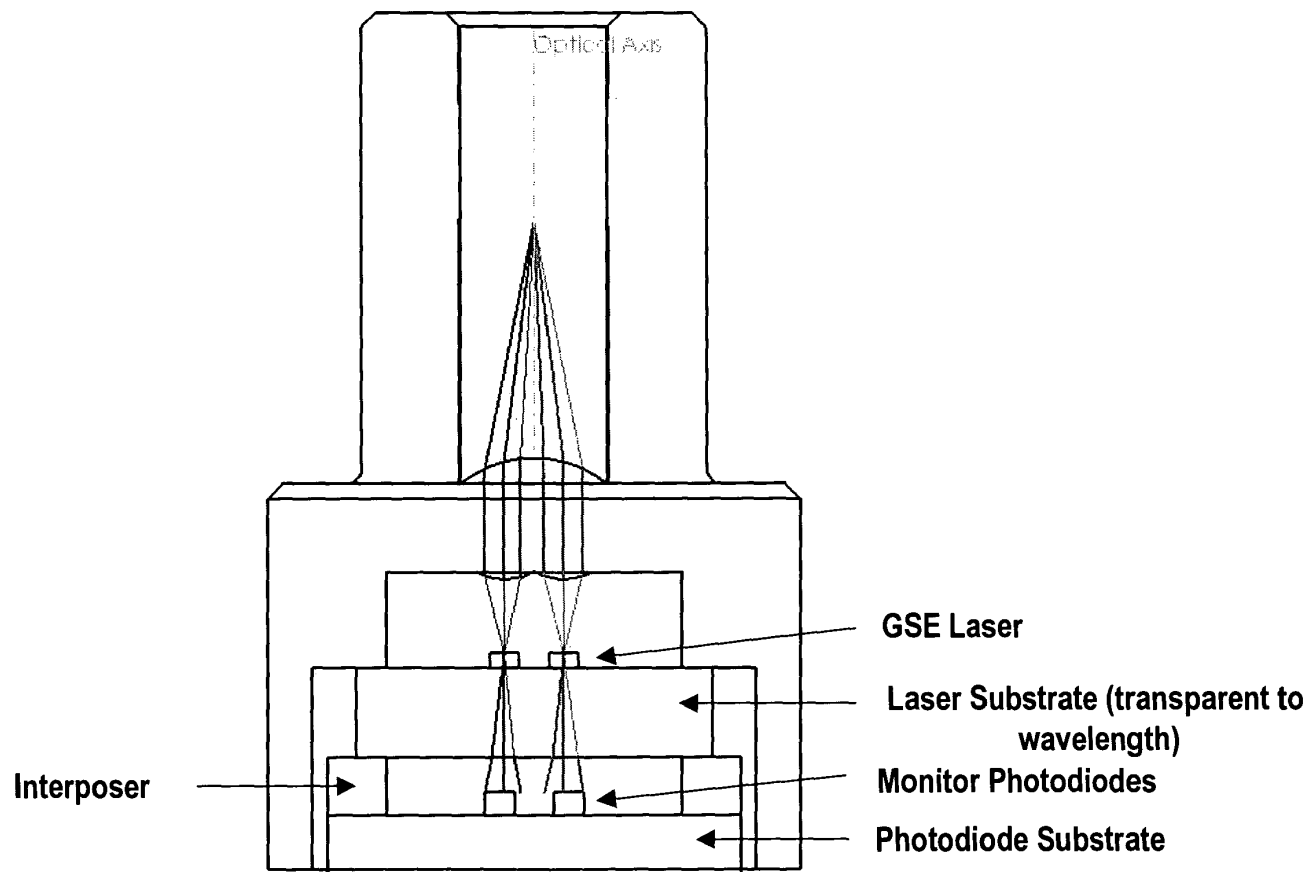
- Integrated monitor PD (within GSE die) is the ultimate solution – needs development
- Interim solution – use backside emission from GSE



- Backside emission from GSE passes through Si substrate
- Monitored by PD's placed under substrate

Photodigm Mux – Monitor Photodiode

Inventor 1 Sarvotham Bhandarkar 9/23/03
Inventor 2 Jaime Castilleja 9/23/03
Witness John Spencer 9/23/03



Photodigm Mux – Monitor Photodiode

Inventor 1

Inventor 2

Witness

Sarvotham Bhandarkar

Jaime Castilleja

John E. Spencer

9/23/03

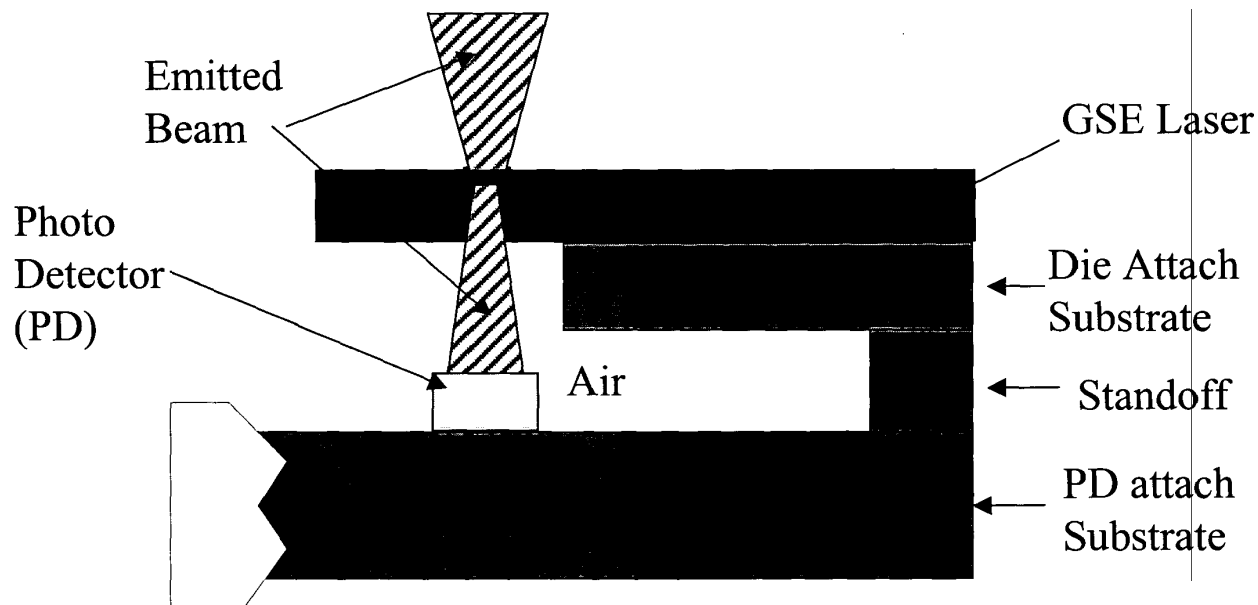
Sarvotham Bhandarkar

9/23/03

Jaime Castilleja

John E. Spencer

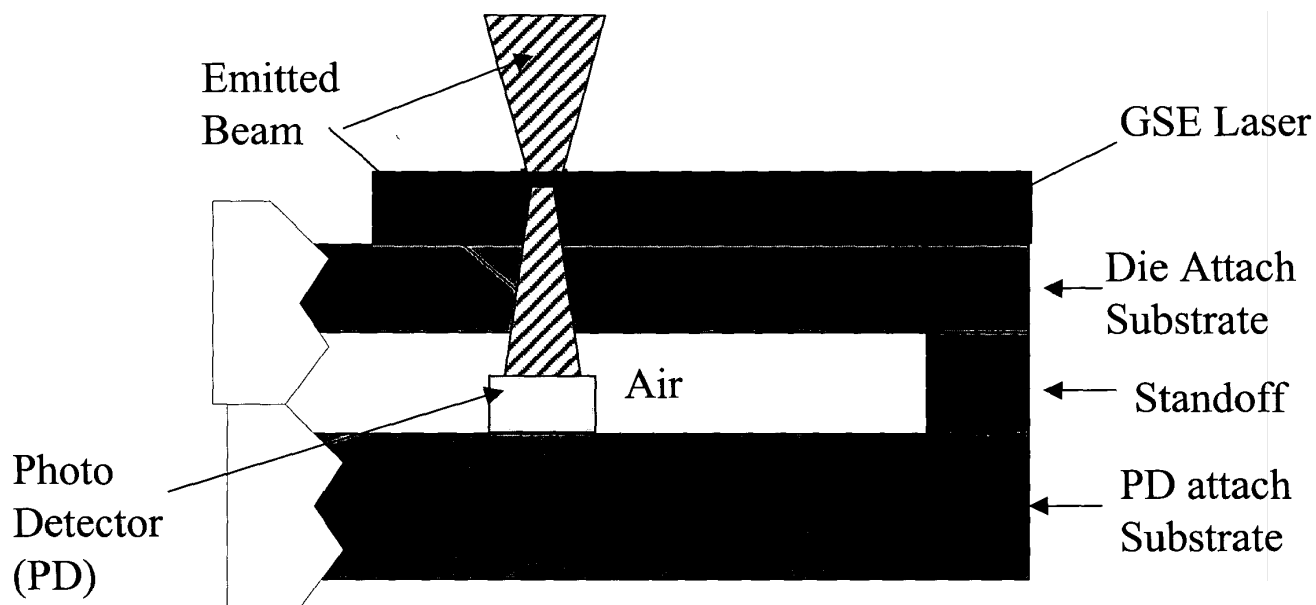
LASER OVERHANGS SUBSTRATE



Photodigm Mux – Monitor Photodiode

Inventor 1 Sarvotham Bhandarkar 9/23/03
Inventor 2 Jaime Castilleja 9/23/03
Witness John E. Spencer 9/23/03

SUBSTRATE TRANSPARENT TO LASER WAVELENGTH

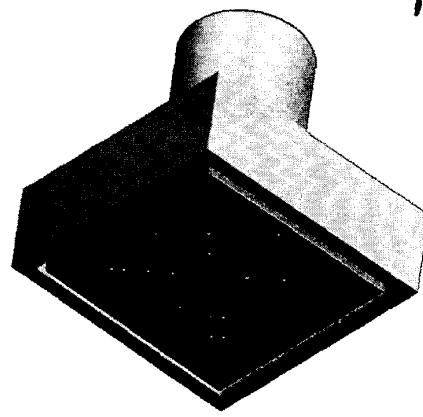
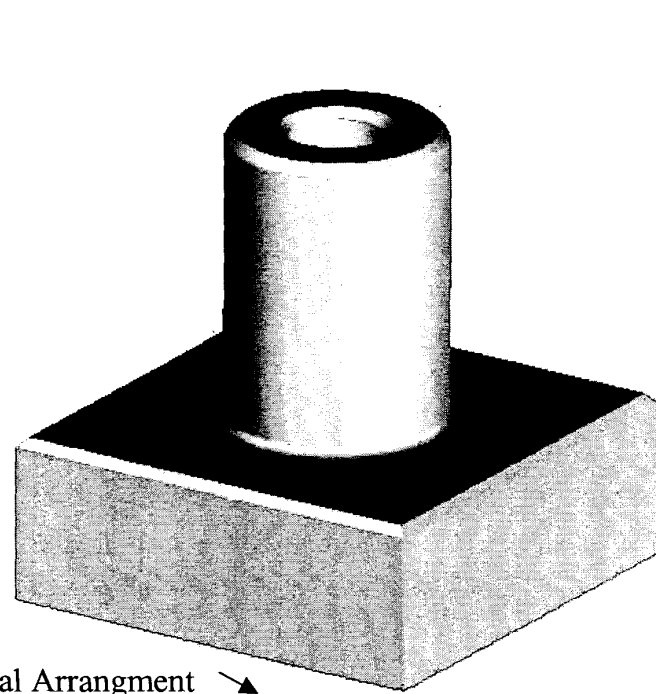


Eight λ Mux

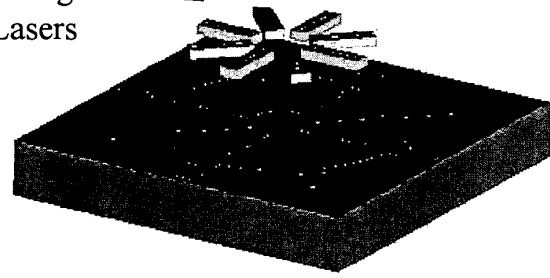
Inventor 1 Sarvotham Bhandarkar 9/23/03 Sarvotham Bhandarkar

Inventor 2 Jaime Castilleja 9/23/03 Jaime Castilleja

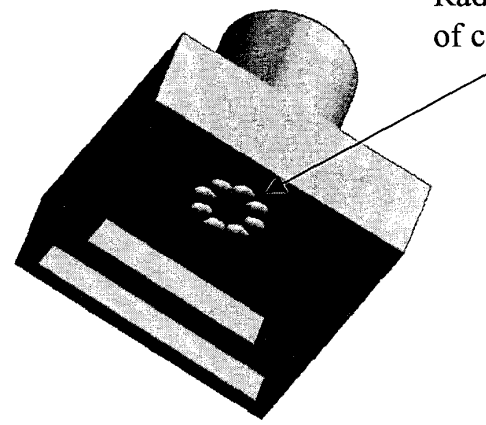
Witness John E. Spencer 9/23/03 John E. Spencer



Radial Arrangement
of GSE Lasers

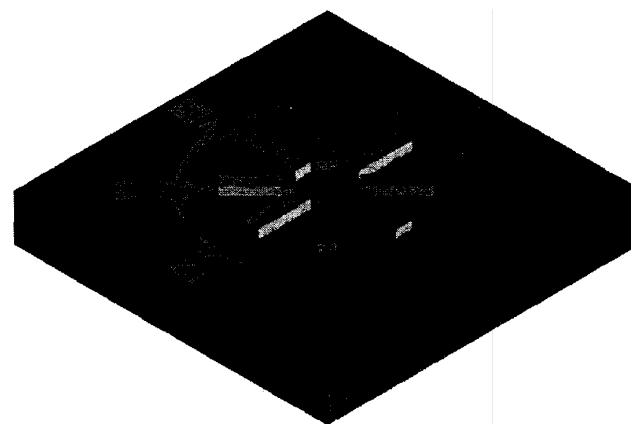
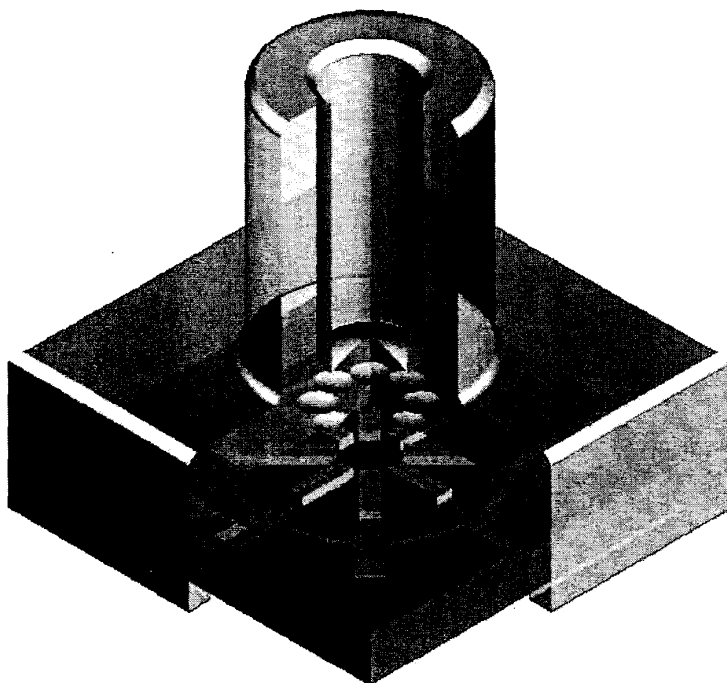


Radial arrangement
of collimating lenses



Eight λ Mux

Inventor 1 Sarvotham Bhandarkar 9/23/03 Sarvotham Bhandarkar
Inventor 2 Jaime Castilleja 9/23/03 Jaime Castilleja
Witness John E. Spencer 9/23/03 John E. Spencer



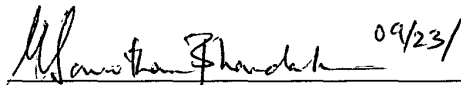
Title : GSE Laser Enabled WDM Mux

Inventors : Sarvotham Bhandarkar Jaime Castillega
2026 Huntcliffe Ct 106 N. Briarcrest
Allen, TX 75013 Richardson, TX 75081

Company : Photodigm Inc, 1155 E. Collins Blvd, Ste 200, Richardson, TX 75081

The WDM Mux proposed in this disclosure consists of an array of GSE lasers attached to a substrate, a matching array of collimating lenses, and a single focusing lens. The divergent laser beam emitted by each laser is collimated by the corresponding collimating lens. The multiple collimated beams are then focused by the single focusing lens into a single spot that is suitable for coupling into an optical fiber. The collimating lens, focusing lens and fiber receptacle are preferably fabricated as one unit by a suitable technology such as precision molding. The laser, collimating lens and focusing lens are laid out in a confocal arrangement. A preferred embodiment shown in the accompanying figure, consists of a 2x2 rectangular array of GSE lasers, each laser at a different wavelength, to yield a four λ mux. The same configuration would yield an eight λ mux with cross grating GSE lasers, with each laser emitting two wavelengths. Another embodiment in the accompanying figures shows an eight λ mux created by a radial arrangement of eight GSE lasers and eight collimating lenses.

The lasers in the mux can be monitored in several ways. In one method, a monitor photodetector is integrated into each GSE laser during the laser fabrication process, and serves to monitor the laser. In another method the backside emission from the GSE laser is collected by a separate monitor photodetector in one of the following methods :- In one method, the laser mount substrate is selected such that it is transparent to the laser wavelength, and the backside emission is collected by photodetectors placed under the substrate. In an alternate method the laser outcoupler region overhangs the edge of the laser mount substrate, allowing the backside emission to be collected by a monitor photodetector placed under the outcoupler. The accompanying schematics describe these various methods.

Inventor 1 :  ^{09/23/03} Sarvotham Bhandarkar

Inventor 2 :  ^{9/23/03} Jaime Castillega

Witness :  ^{9/23/03} John Spencer

CLAIMS:

What is claimed is:

1. A laser-enabled multiplexing system, comprising:
a first plurality of lasers;
a second plurality of lenses, each lens of said second plurality of lenses positioned so as to collimate a beam of light emitted by a laser of said first plurality of lasers; and
a third lens, said third lens positioned to focus a plurality of collimated beams of light received from said second plurality of lenses into substantially a point of light.
2. The laser-enabled multiplexing system of Claim 1, wherein said each lens of said second plurality of lenses is positioned so as to collimate said beam of light emitted by a corresponding laser of said first plurality of lasers.
3. The laser-enabled multiplexing system of Claim 1, wherein said first plurality of lasers comprises a plurality of Grating-outcoupled Surface Emitting (GSE) lasers.
4. The laser-enabled multiplexing system of Claim 1, wherein said first plurality of lasers comprises a plurality of semiconductor lasers.
5. The laser-enabled multiplexing system of Claim 1, further comprising:
a receptacle for coupling said point of light to an optical fiber.
6. The laser-enabled multiplexing system of Claim 1, wherein at least one of said said first plurality of lasers, at least one of said second plurality of lenses, and said third lens are arranged in a confocal configuration.
7. The laser-enabled multiplexing system of Claim 2, wherein said second plurality of lenses, said third lens, and said receptacle are fabricated as a single unit.

8. The laser-enabled multiplexing system of Claim 1, wherein said first plurality of lasers comprises an array of at least 2 lasers.
9. The laser-enabled multiplexing system of Claim 1, wherein said first plurality of lasers comprises a 2-by-2 rectangular array of lasers.
10. The laser-enabled multiplexing system of Claim 8, wherein said second plurality of lenses comprises a 2-by-2 rectangular array of lenses.
11. The laser-enabled multiplexing system of Claim 1, wherein said first plurality of lasers comprises an n-by-n array of lasers.
12. The laser-enabled multiplexing system of Claim 10, wherein said second plurality of lenses comprises an n-by-n array of lenses.
13. The laser-enabled multiplexing system of Claim 1, wherein said first plurality of lasers comprises a radial array of lasers.
14. The laser-enabled multiplexing system of Claim 12, wherein said first plurality of lasers comprises a radial array of 8 lasers.
15. The laser-enabled multiplexing system of Claim 1, wherein said second plurality of lenses comprises a radial array of 8 lenses.
16. The laser-enabled multiplexing system of Claim 1, further comprising:
a substrate, said first plurality of lasers attached to said substrate.
17. The laser-enabled multiplexing system of Claim 1, wherein said multiplexing system comprises a Wavelength Division Multiplexer (WDM).

18. The laser-enabled multiplexing system of Claim 1, further comprising:
at least one photodetector, said at least one photodetector coupled to at least one laser of said first plurality of lasers so as to monitor an energy output from said at least one laser.
19. The laser-enabled multiplexing system of Claim 17, wherein said at least one photodetector is integrated into said at least one laser of said first plurality of lasers.
20. The laser-enabled multiplexing system of Claim 17, wherein said at least one photodetector is operable to receive a backside emission of energy from said at least one laser of said first plurality of lasers.
21. An output monitor for a laser-enabled multiplexing system, comprising:
a plurality of lasers;
a substrate attached to said plurality of lasers for mounting said plurality of lasers, said substrate including a transparent portion; and
a plurality of photodetectors, each photodetector of said plurality of photodetectors located adjacent to said transparent portion of said substrate on a side of said substrate opposite that of said plurality of lasers so as to receive a backside emission of energy from at least one laser of said plurality of lasers.
22. An output monitor for a laser-enabled multiplexing system, comprising:
a plurality of lasers, each laser of said plurality of lasers including an outcoupler region;
a substrate attached to said plurality of lasers for mounting said plurality of lasers, said substrate including a portion not attached to each said outcoupler region of each laser of said plurality of lasers; and
a plurality of photodetectors, each photodetector of said plurality of photodetectors located adjacent to a corresponding outcoupler region of each laser of said plurality of lasers so as to receive a backside emission of energy from at least one laser of said plurality of lasers.

23. A method for multiplexing a plurality of laser beams, comprising the steps of:
emitting a beam of light from each laser of a plurality of lasers;
collimating each said beam of light emitted from said each laser of said plurality of lasers; and
focusing said plurality of collimated beams of light into substantially a point of light.
24. The method of Claim 22, wherein said plurality of lasers comprises a plurality of GSE lasers.
25. A method for monitoring an output of a laser-enabled multiplexing system, comprising the steps of:
emitting a beam of light from each laser of a plurality of lasers;
attaching a substrate to said plurality of lasers, said substrate including a transparent portion; and
a plurality of photodetectors located adjacent to said transparent portion of said substrate on a side of said substrate opposite that of said plurality of lasers and receiving a backside emission of energy from at least one laser of said plurality of lasers.
26. The method of Claim 24, wherein said plurality of lasers comprises a plurality of GSE lasers.
27. A method for monitoring an output of a laser-enabled multiplexing system, comprising the steps of:
emitting a beam of light from an outcoupler region of each laser of a plurality of lasers;
attaching a substrate to said plurality of lasers, said substrate including a portion not attached to each said outcoupler region of each laser of said plurality of lasers;
locating a plurality of photodetectors adjacent to a corresponding outcoupler region of each laser of said plurality of lasers; and

at least one photodetector of said plurality of photodetectors receiving a backside emission of energy from at least one laser of said plurality of lasers.

28. The method of Claim 26, wherein said plurality of lasers comprises a plurality of GSE lasers.