Authors: Tiberius, Francois, Jonathan, Frederic (orange), add your name here,

Design Optical - Mosquito

under heavy construction...

If you contribute to this doc **make sure you respect** the Content rules

This document illustrates different designs of optical layer of the Mosquito Sensor.
This is a project of SENSORICA, an open, decentralized, and self-organizing value network, designing, producing and distributing optical fiber-based sensors.

Table of contents

Authors: Tiberius, Francois, Jonathan, Frederic (orange), add your name here,

Known problems with LD Mosquito designs

Light get's back to the LD and induces chaotic intensity fluctuations. Frederic thinks that we need to reach 60dB attenuation of the return signal.

Tested and Proposed solutions

Isolator

We tried the design with chinese parts, using an isolator after the LD with Multi-Mode Fiber. This was extensively tested with the Chinese parts (see specs for LD + Isolator) and did not work properly, the Mosquito signal fluctuates a lot. See *design 2-pass device with 1x2 coupler and isolator*
The problem is that the MM fiber scrambles the polarization of the light, and the isolator is polarization-based.

Circulator

This was tested briefly by jonathan, but more work needs to be done on it.
See design 2 pass device with circulator. See bill here.
It came with specs, a test data sheet that we need to find in the lab.

OZ Optics packaged devices that reduce the return loss

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Offering from OZ-Optics with attenuation for return signal.
OZ-Optics can go up to 60dB attenuation of the return signal. See more on this doc, page 5.
These are devices are like those in examples 5 and 6 in this doc. They claim to use a **tilting technique** where the back reflection is not aligned with the laser cavity. Search for the Mosquito SS4 design.

Spatial filtering

Proposed by Jonathan and Tibi. See diagram here. Frederic things this is not enough. The idea is to create a spatial asymmetry and have good coupling going from the laser to the application (a force transducer) and bad coupling for the light going back. See link to the diagram. The SM signal from the laser will be efficiently coupled to the MM fiber that goes to the transducer. When this SM light travels within the MM fiber it gets converted into MM, and on its way back, the exit of the MM fiber will become a broad surface light source, which will be focused back by the lens. But only a small fraction of it will get coupled back into the SM fiber.
NOTE: Frederic D. thinks this is not enough

Light sources

From Frederic: In order to have a very stable light source, one possibility would be to use a LED or a super-luminescent diode (see for example Thorlabs). LED's are very inexpensive, but would result in very low power coupled into the fiber. Superluminescent diodes (SLD or SLED) would have similar power in the fiber as a LD, but price is relatively high (~$1,500). Qphotonics offers a full line of SLED. Their 1550nm fiber-coupled model costs $790.

LD (laser)Single wavelength *bidirectional PD-LD*

This is the configuration that was used for the first Mosquito prototype, in the Demo Mosquito and in Phil's first Mosquito.

Last Modified on May 30, 2012. Please keep us updated if you adopt this model and make improvements.
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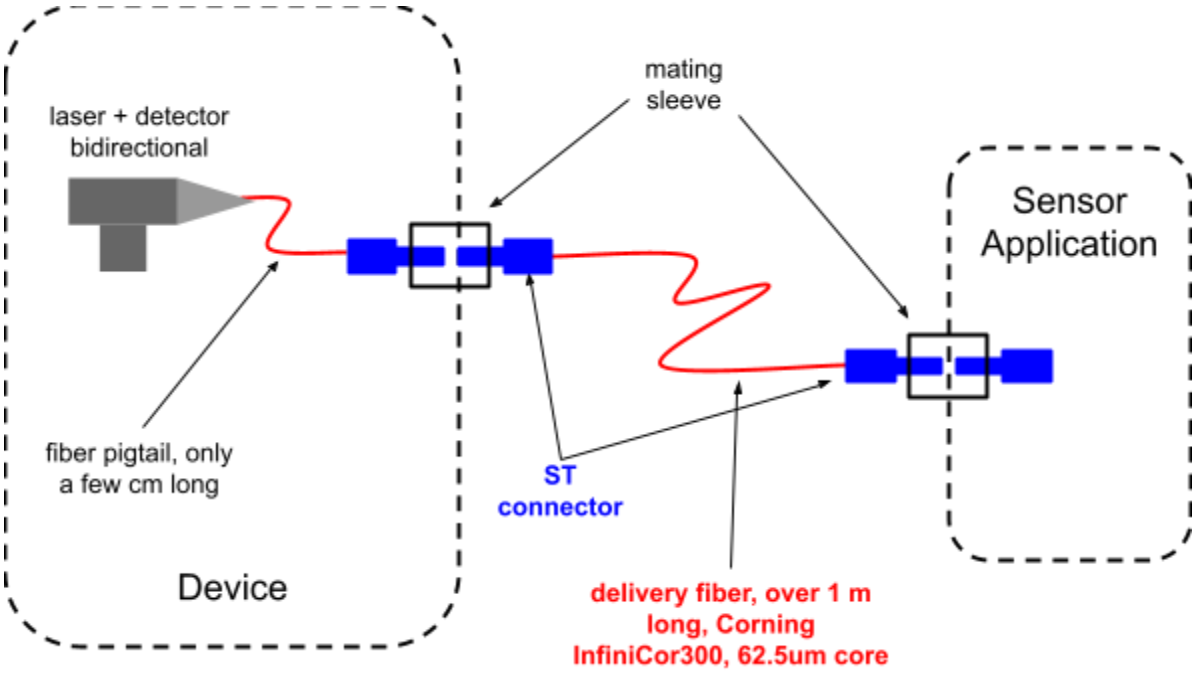

A laser signal is emitted by the laser (see *laser + detector*) and transported to the *Sensor Application*. From the sensor application the laser signal is sent back through on the same path towards the detector (see *laser + detector*). There are some optical connections in between.

The problem with this configuration is that the reflected light goes back into the laser. Considering that there is typically a 50/50 beam splitter inside the laser+detector, and that the sensor reflects ~100% of the light incident on it (light delivered by the delivery fiber), that means that about 25% of the light emitted by the laser is reflected back into it. Under such conditions, the laser becomes very unstable. The light reflected back into the laser needs to be no more than a few % of its emitted light in order to remain stable. Experiments recently performed (Jan 2013) indicate that even a very small fraction of less than 0.1% will generate some instabilities (or noise).
In order to have a very stable light source, one possibility would be to use a LED or a super-luminescent diode (see for example Thorlabs). LED's are very inexpensive, but would result in very low power coupled into the fiber. Superluminescent diodes (SLD or SLED) would have similar power in the fiber as a LD, but price is relatively high (~$1,500).
Qphotonics offers a full line of SLED. Their 1550nm fiber-coupled model costs $790.

laser + detector

The device is similar to the device in the picture below - Layout.

- The *laser* and the *detector* MUST be of the **same wavelength**, because the detector must detect the emission of the laser as it comes back from the *Sensor Application*. We can work at 1.5 or 1.3 microns.

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- The laser needs to be **multi-mode** (see delivery fiber below).
  The laser can be single-mode as well. The fact that it is coupled into a MM fiber does not matter. In fact, most of the 1300-to1500nm lasers are derived from telecom devices which are single mode. In this context, single mode refers to the spatial characteristics of the laser beam, and not its frequency characteristics.
- The device can be terminated with a **pigtail OR an *ST* connector**.

Can type for detector is TO46

Beam splitter

We need to recover ~100% (or as much as possible) of light that comes from the application. We can use a PBS beamsplitter. The laser signal is sent back to the detector after a reflection on a metal mirror.

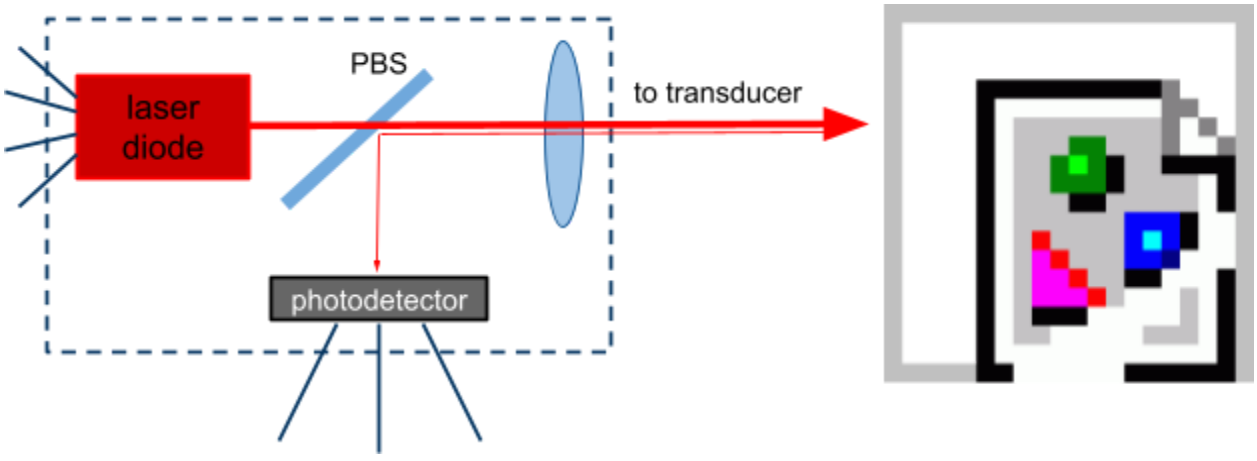
Photodetectors are very sensitive, they need very little light to generate a good signal.

Delivery fiber

The delivery fiber needs to be multi-mode. We are using Infinicore300 62.5 core.

Why does the fiber need to be multi-mode? Multi-mode fibers tend to be less expensive than single-mode fiber, and they are more tolerant to misalignment, but for this application, the difference is in my opinion (Frederic) minimal. For the moment, it may make sense to stick with MM fiber just because there no specific reason to go SM. But we may decide otherwise later. For example, polarization discrimination would be more straightforward and easier with SM-PM (polarization-maintaining) fiber.

Layout



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Development setup solution

Based on Thorlabs materials as an example

Part	Picture	Prix
FiberBench/FiberTable Mirrors and Beamsplitters		400 $
The polarizing beamsplitter 5mm cube		143 $
Fiber Bench		219 $

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Complete solution or something like this	 	

LD (laser) Modular optical fiber designs

The red fiber in the diagrams below is our delivery fiber, Infinicor300, multimode, 62.5/125 microns core/OD from Corning. We work at 1550 nm, we use ST-UPC connectors. See more details on the educational doc about assembly of fiber-based modular devices

LD (laser) 2-pass device with circulator

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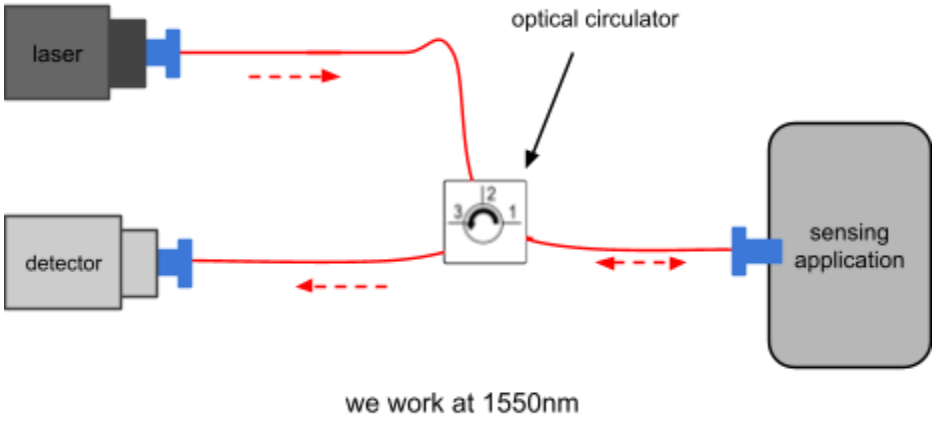
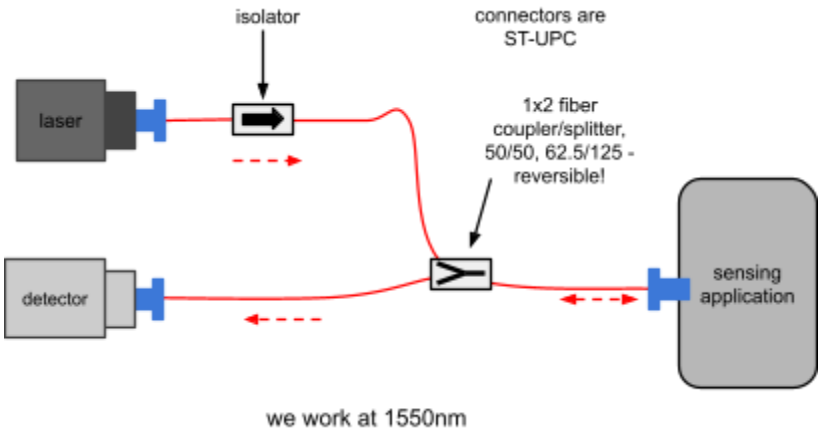


This would work very well with SM-PM fiber. A true optical circulator cannot work with MultiMode fiber or non-PM fiber.
We ordered a MM circulator from China, not tested it extensively, needs more test.
The circulator doesn't work well because polarization is not maintained in the MM fiber.

LD (laser) 2-pass device with 1x2 coupler and isolator



This was built with the Chinese photonics parts. (see specs for LD + Isolator), tested, but doesn't work properly because it gets too much signal back into the LD and makes that LD fluctuate. The MM fiber doesn't preserve polarization.

LD (laser) multipass device with 1x2 coupler and isolator

Never tested!

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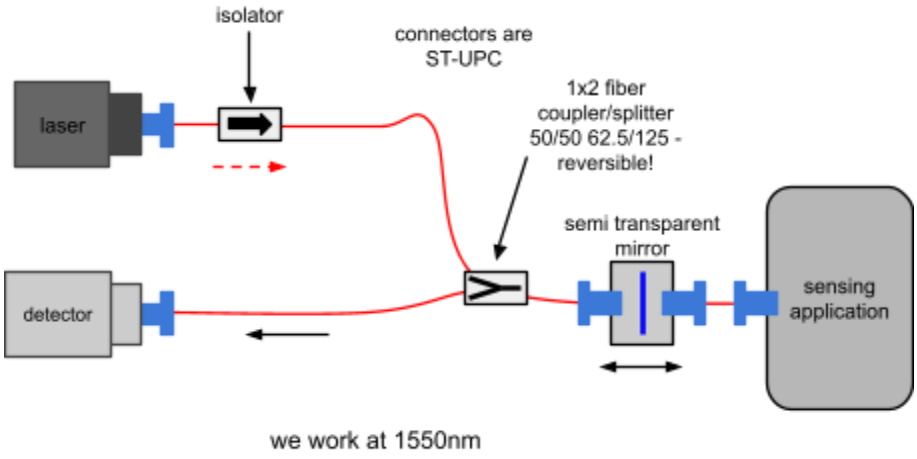
This is similar to the previous design, with a semi-transparent mirror in-line between the *1x2 fiber coupler 50/50 62.5* and the *application*. This semi-transparent mirror forms a cavity which traps the light within the transducers for multiple passes. A similar design would be used for the device with coupler.



Frederic: This configuration does not provide any advantage at all, except as frequency discrimination.

2-pass device with 1x2 10-90 coupler

Never tested!

One simple way to reduce the amount of light being reflected and fed back into the laser is to use a coupler/splitter with an unbalanced splitting ratio such as 10%/90% instead of 50/50. In this case, as illustrated below, only about 1% of the light emitted by the laser can be reflected back into it. This reduces somewhat the amount of light collected by the detector, but only by a factor of about 2.8 (the use of a 50/50 splitter would return 25% of the light emitted by the laser into the detector instead of 9% for a 10/90 splitter).

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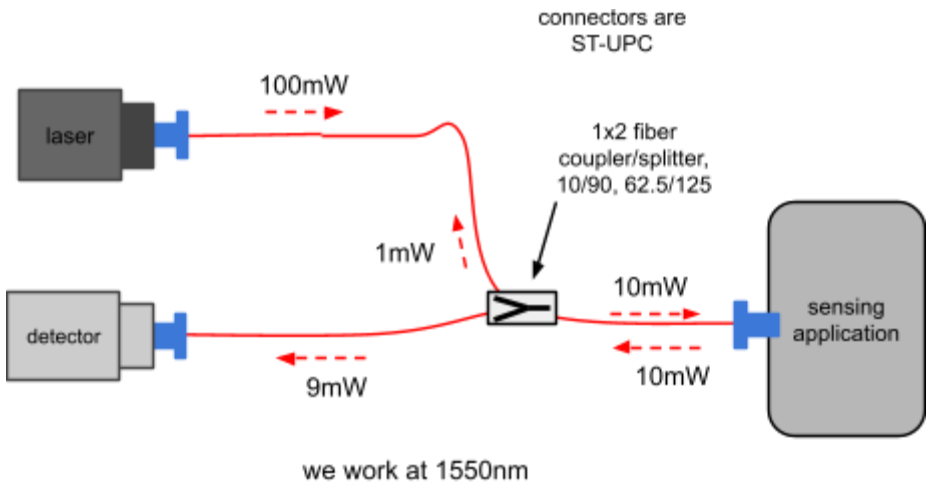

Such fiber splitter is readily available from Thorlabs FCMM625-90A.
Unfortunately, after testing (Jan 2013), we found that such fiber splitter is NOT reversible. When the laser is launched into the 10% fiber, only about 0.1% of it comes out of the common fiber. And we still observed instabilities in the laser output when light is reflected from the sensor.

LD (laser) dual wavelength Mosquito

Never tested!

In this design a broadband laser is used. A dichroic mirror in front of the sensing application transmits only a narrow band, which goes through the sensitive area and comes back to recombine with the rest of the light, and reaches the beam splitter, where it is separated again to be sent to a detector S. The rest of the light, which has travelled through the environment but has reflected on the dichroic mirror goes through the second beam splitter to reach the detector R. The detector S measures the signal, containing information from the sensing application. The detector R measures a reference signal, i.e. a signal that has suffered the same influence from the environment like the signal. We assume that the environment influence is not wavelength dependent.

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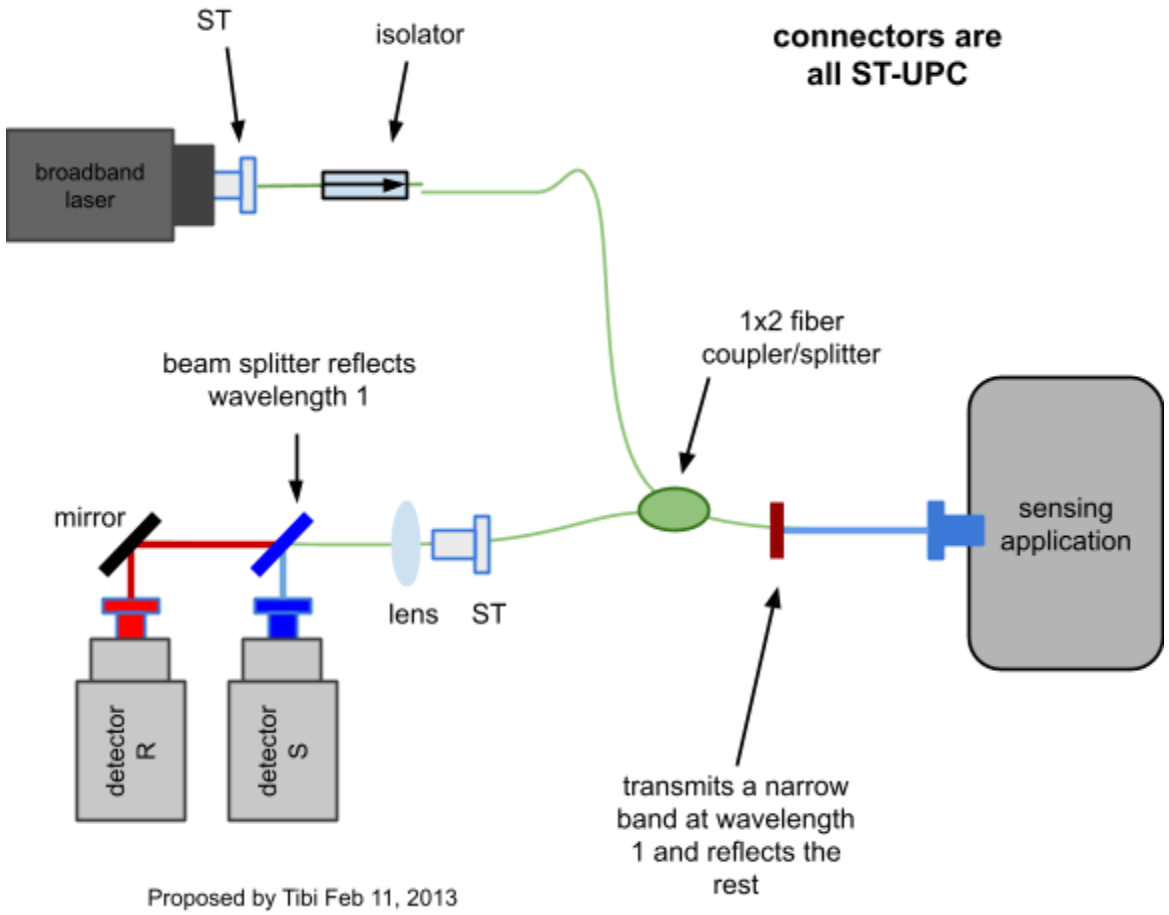

LD (laser) pulsed Mosquito

See its own document.

LD (laser) SS4 Mosquito

open electronics design doc
Open optical design doc

LED Mosquito at 850nm

Successfully tested on April 02, 2013 by Jonathan, Tibi and Daniel.

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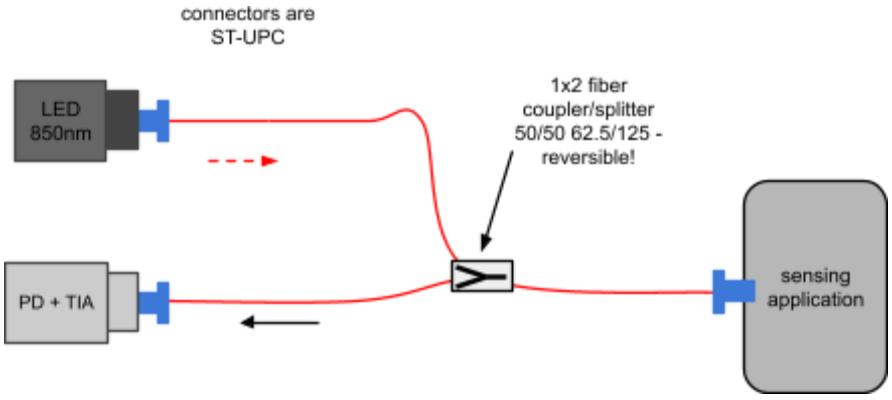
See more on its own document.

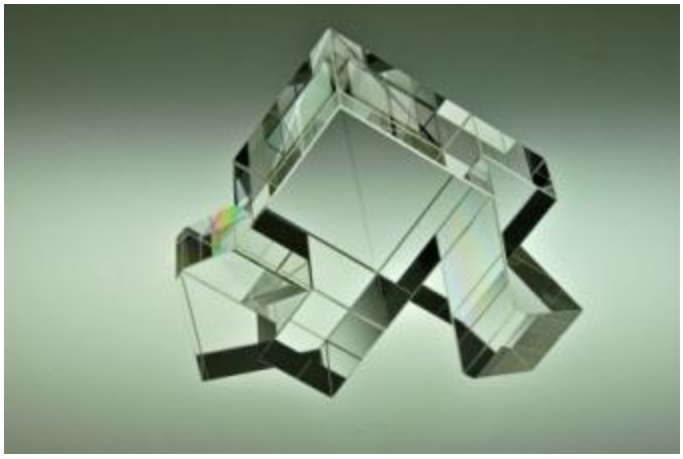


LED Mosquito in the visible

Open doc

Monolithic optical assemblies

This is another design option. See example in the picture below.
See doc from Agilent http://cp.literature.agilent.com/litweb/pdf/5989-3091EN.pdf



Different modules

Authors: Tiberius, Francois, Jonathan, Frederic (orange), add your name here,

PIN TIA bidirectional

1490nmTx/1310nm PIN-TIA Rx BiDi Module

ROSA pin-tia receiver 1.25G LC connector 850nm, 1310 ,1550nm PIN+TIA
ROSA = ReceiverOpticalSub-Assembly

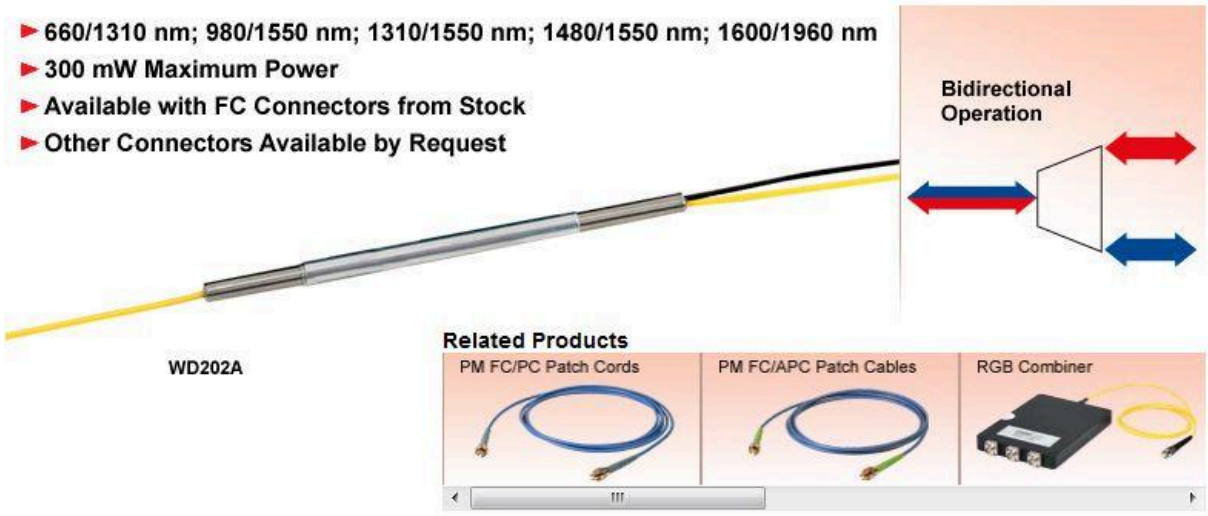
digikey.ca
http://search.digikey.com/ca/en/products/OED-PPD11075G-B/67-1505-ND/286955
http://search.digikey.com/ca/en/products/MTPD1346-010/1125-1027-ND/2798893
http://search.digikey.com/scripts/DkSearch/dksus.dll?x=0&y=0&lang=en&site=ca&KeyWords=photodiode

Optical fiber insulators

http://www.alibaba.com/product-gs/510981381/PM_Fiber_Dual_stage_isolator.html?s=p

Wavelength Division Multiplexers (WDMs)

From Thorlabs



Optical fiber termination and connection

http://www.thorlabs.com/NewGroupPage9.cfm?ObjectGroup_ID=354

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