Coupling to ROD fibers

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This application note addresses how to couple signal and pump light to and from a simple reverse pumped amplifier based on a Crystal Fibre ROD fiber. Where possible, suggestions are given for part numbers and specifications.
The current version of the note does not cover optimization of fiber length, end-caps or amplifier parameters.

Setup

The seed and pump coupling setups are illustrated in figure 1 and figure 2. In figure 1 seed light is coupled from a delivery fiber into the rod fiber through a free space optical isolator using a set of mode matched lenses. λ/2-plates are used for control of the seed polarization. In figure 2 pump light is coupled from a delivery fiber into the rod fiber in the backward direction using a set of high NA mode matched lenses. The signal light is extracted using a dichroic mirror.

Seed Coupling

Lens selection

ROD fibers feature a signal core with a very low numerical aperture (NA) and good seed coupling is best obtain by using a lens with a long focal length and a small NA (such as a *LA1608-B*, f = 75mm from Thorlabs).
When choosing a collimating lens for mode matching, one can use the fiber collimation equation:

$$f = \frac{\pi D(MFD)}{4\lambda}$$

where f is the focal length, D is the diameter of the collimated beam between the two lenses, and *MFD* is the mode field diameter.
D should be smaller than the aperture of the isolator to avoid beam clipping. Using a signal delivery fiber with *MFD* = 12.6µm, a lens choice could e.g. be *Thorlabs CM280TME-B, f = 18.4mm*. In this case $D \approx 1.7$mm.

Isolator

It is recommended that the seed system is protected with a 1064nm isolator to avoid damage and instability. When selecting an isolator, be careful to match the isolator with the expected power of the system. With a PM seed delivery fiber use a polarization dependent isolator e.g. *Thorlabs OFR IO-5-1064-VHP* for max 60W and a max beam diameter of 3.1mm.

λ/2 plates

Use a λ/2-plate before the polarization dependent isolator for alignment of the

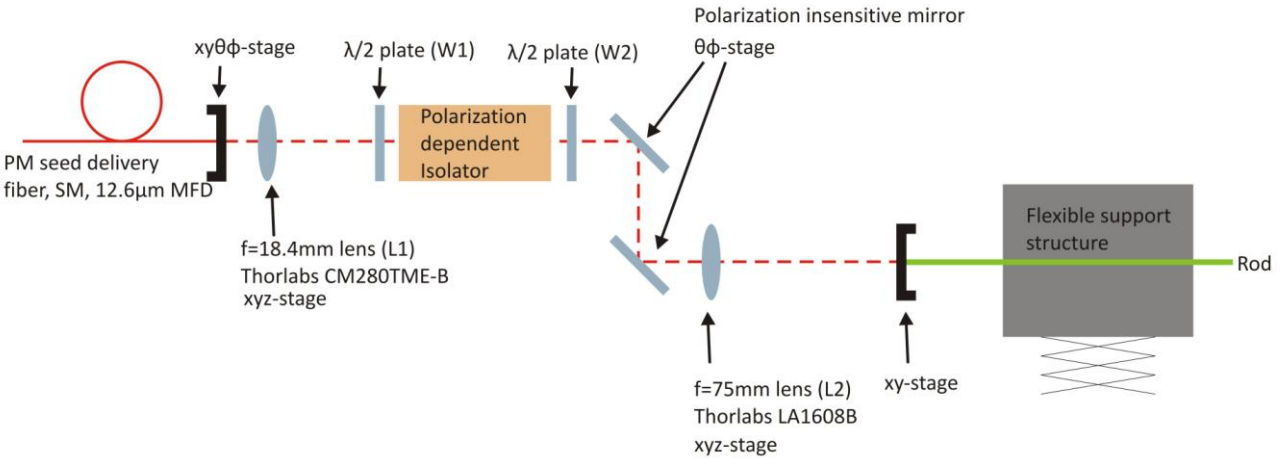

Figure 1 Setup for seed coupling. The seed light is coupled from a delivery fiber into the rod fiber through a free space optical isolator using a set of mode matched lenses. λ/2-plates are used for control of the seed polarization.

polarization axis. For PM ROD fibers it is further recommended to use a λ/2-plate after the isolator to align the polarization. For non-PM ROD fibers the last λ/2-plate can be omitted. Suitable λ/2-plates could be e.g. *Thorlabs WPH05M-1064*.

Mirrors

For PM ROD fibers choose mirrors that are insensitive to polarization in order to preserve the linear polarization out of the isolator. Use e.g. unprotected gold mirrors, *Layertec Bare Gold.* The mirrors provide angular adjustment of the seed beam.

Stage

Ensure sufficient degrees of freedom to control the seed coupling, e.g. mirrors for the θϕ-control and xy-control of the rod position.
Use e.g. *OWIS Small Mirror Mount* for θϕ-control and *OWIS XY-Fine Adjustment Stage* for xy-control. Always have xyz-control of the coupling lenses, e.g. *OWIS Miniature 2-Axis Stage MVT xyz*.

Rod support

The ROD fiber should be supported during operation to avoid bending stress and movement as this can degrade the performance of the fiber.

Pump Coupling

Lens selection

For pump coupling choose a set of lenses with high *NA* in order to make use of the high *NA* of the pump cladding. Use the fiber collimation equation for mode matching. With a standard 125µm fiber use e.g. *Asphericon, f = 10mm, NA = 0.545*, for pump collimation and *Asphericon, f = 15mm, NA = 0.534* for pump coupling.

Filter

Use a long wave pass filter to reflect the pump light and transmit the signal output, e.g. *Layertec HRs+p(22.5°,820-990nm)*. Use a short wave pass filter for extra protection of the pump diodes, e.g. *Layertec HRs+p(22.5°,signal wavelength)*.

Stages

For θϕ-control of the pump coupling use e.g. *OWIS Transmitting Mount TRANS 40L* with the long wave pass filter. For xy-control of the pump coupling use e.g. *OWIS XY-Fine Adjustment Stage* for positioning the pump delivery fiber and the ROD fiber. For xyz-control of the lenses use e.g. *OWIS Miniature 2-Axis Stage MVT xyz*.

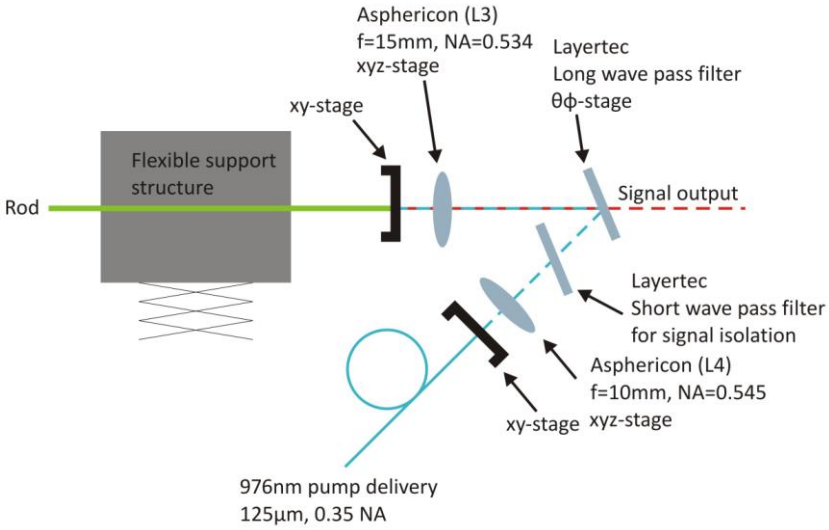

Figure 2 Setup for pump coupling. The pump light is coupled from a delivery fiber into the rod fiber in the backward direction using a set of high NA mode matched lenses. A dichroic mirror is used for extraction of the signal light.

Coupling Procedure

IMPORTANT: Always turn on the seed signal and ensure good coupling before activating the pump lasers. A pumped and unseeded ROD fiber will store a lot of energy that will eventually be released as a spontaneous pulse. This can happen within seconds. These pulses have very high peak power, and can damage both fiber and other equipment.

For Non-PM use

- Insert the pump collimating lens, L4.
- Collimate and align the pump light such that the beam is centered and parallel with the ROD fiber.
- Insert the pump coupling lens, L3.
- Couple ~600mW of pump light into the ROD.
- Observe an ASE spot at the seed input end by imaging the far field from the input end onto a white screen. Use just enough pump power for ASE spot to appear.
- Insert the seed collimating lens, L1.
- Collimate and align the seed light.
- Insert the isolator.
- Optimize the seed output through the isolator by adjusting the λ/2-plate, W1.
- Overlap the ASE spot with the seed beam at two points e.g. close to the ROD fiber and close to isolator.
- Insert the seed coupling lens, L2.
- Overlap the ASE spot with the seed beam again at a single point.
- Measure the signal output from the core of the ROD fiber .
- Optimize the seed coupling by walking the beam for maximum core/clad ratio. Only use the stages after the isolator. Use a power meter and an iris for measuring the core light. The core/clad ratio should be >4dB.
- Optimize the pump coupling by walking the beam. Do not move the stages holding the ROD or lens L3 as this will move the beam relative to the iris.

For PM use

- Identify the slow or fast axis of the ROD fiber by pumping the ROD fiber lightly and imaging the output onto a screen using the seed coupling lens. The stress elements are visible with a IR viewer.
- Align the polarization of the seed beam with the slow or fast axis of the ROD fiber by rotating the λ/2-plate, W2, after the isolator. The polarization axis can be found by using a polarizer, e.g. *Thorlabs, Glan Laser Polarizer, GL10-B.*