Getting the most out of your Conoptics Optical Isolator

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1 Isolator Uses

Optical isolators are used in our lab to protect diode lasers from optical feedback. Unwanted optical feedback can lead to frequency instability or, worse, break the or destroy the laser diode inside the laser. Use of an optical isolator helps to solve both these problems. We employ optical isolators with three types of diode lasers (all CW) in our lab:

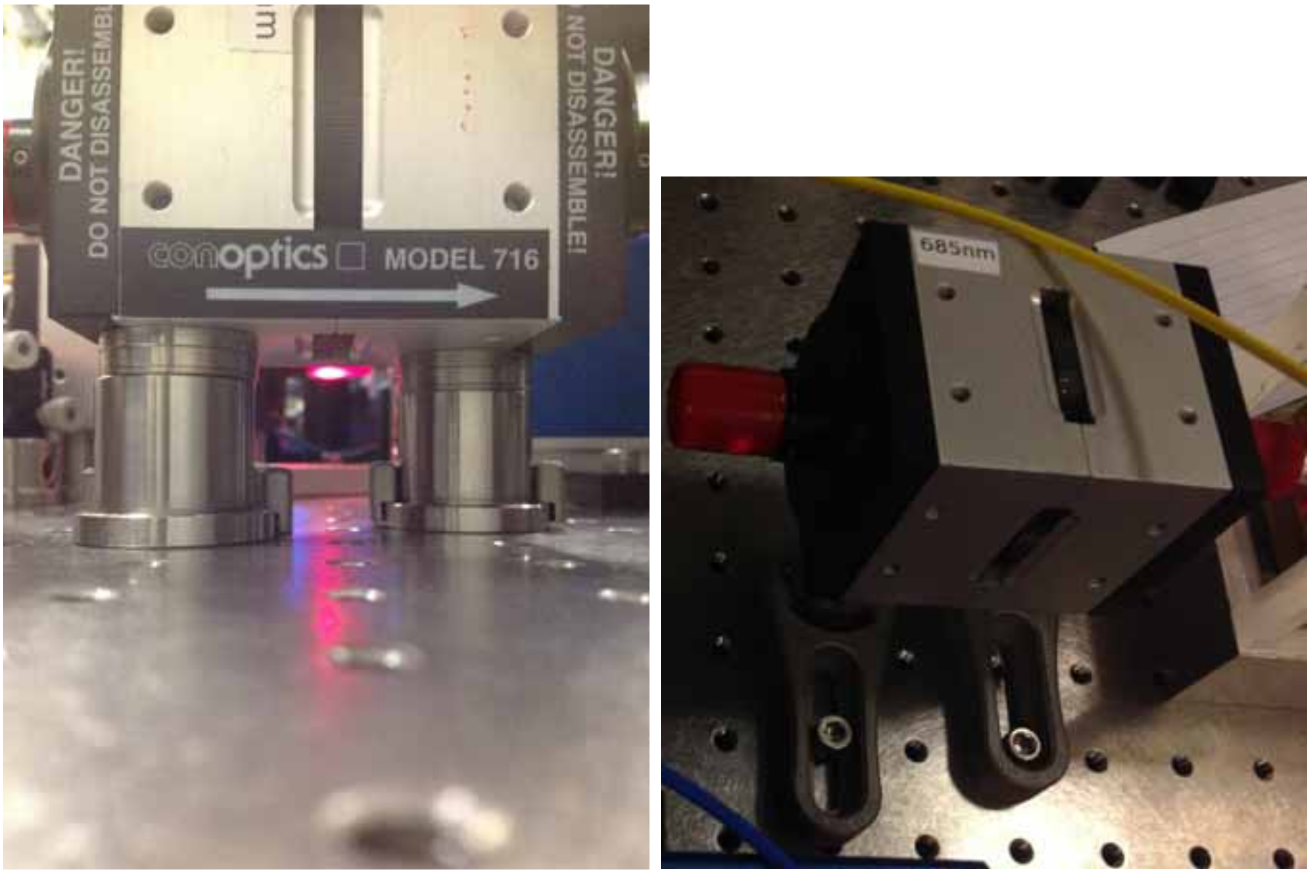
1. **External Cavity Diode Lasers (ECDL)**. These are master lasers and are either used on their own or to seed higher power amplifiers. These lasers are very sensitive to optical feedback. Unwanted optical feedback typically results in the frequency of the laser shifting erratically.
2. **Tapered Amplifiers**. These lasers are used to amplify light to achieve higher output powers than can be typically achieved using an ECDL alone. Due to their high output powers (typically 500 mW - 2 W) an optical isolator is usually necessary on the output to prevent the tapered amplifier from being damaged by unintended optical feedback. Tapered amplifiers typically emit a few mW of light towards the seed laser.
3. **Slave Lasers**. These lasers are used to amplify seed light to achieve output powers that are typically higher than can be achieved using an ECDL alone but lower than that possible with a tapered amplifier. While a slave laser performs the same function as a tapered amplifier, the former generally produce less power and are used when tapered amplifiers are either unavailable at a given wavelength or not feasible due to cost.

2 When do you need an optical isolator?

In comparison to single frequency lasers employing ring cavities such as Ti:Sapphire lasers or dye lasers, ECDLs are particularly sensitive to optical feedback. Unlike the above lasers, ECDLs have no intra-cavity element which acts to attenuate light sent back towards the laser. The following rules give a general idea of what isolation is required for diode lasers under what conditions.

- Standard ECDL free spaced coupled to an experiment unlikely to send large amounts of light back towards the laser - A 30 dB isolator is probably fine here but more isolation might be required depending on the application.
- Standard ECDL coupled into a fiber - A 30 dB or 60 dB isolator is generally necessary. When coupling into fibers, we use only APC (angle polished fibers which minimize back reflections. Regular FC fibers tend to reflect significant amounts of light back towards the laser and are to be avoided.

- Standard ECDL seeding a tapered amplifier either via free space or through a fiber - A 60 dB isolator is typically required here since tapered amplifiers typically send a few mW of power backwards towards the seed laser.
- Standard ECDL seeding a slave either via free space or through a fiber - A 30 dB or 60 dB isolator is typically required here. Similar to tapered amplifiers setups, slave laser setups can send up to a few mW of light back towards the seed laser depending on the setup.
- Slave laser - A 30 dB isolator is generally sufficient here.
- Tapered Amplifier - While a 30 dB isolator is likely sufficient here for most applications, we use 60 dB isolators on the output of the tapered amplifier since we sometimes expect large amounts of power to be reflected back towards the tapered amplifier.



(a) (b)

Figure 1: Standard mounting of a Conoptics 716 optical isolator on 1 inch diameter steel pedestal posts (left) and clamping of the posts to the optical table (right). The height of the isolator is matched exactly to the height of the laser using commercially available stainless steel shims.

3 Initial alignment

The isolators are typically mounted using a pair of 1 inch diameter pedestal style steel posts. To match the isolator height exactly to the laser, we use commercially available steel shims as shown in Fig. 1. Optical isolators create strong magnetic fields. To minimize possible damage to the isolator (especially to the polarizers) we use berillium copper tools when adjusting the optical isolator or optics near the isolator. To further protect the delicate polarizers we cut holes in the protective rubber caps of the isolator and leave the caps on as shown in Fig 2. For our power levels, this practice is not problematic.

We generally send our lasers directly through the optical isolator with no beam steering mirrors in between the isolator and the laser. If the isolator is already at the right height vertically and the output of the laser is level, this involves manually moving the isolator on the optical table. Since the 5 mm apertures are large enough so that our typical laser beams can pass through without any clipping, proper alignment through the isolator is usually done by eye. Specifically, we check that the laser beam is centered on the isolator's input polarizer and centered on the isolator's output polarizer and shows no evidence of clipping after having passed through the isolator. A picture showing a red laser centered on the isolator input is shown in Fig. 2. Once the laser beam is centered on the input and output polarizers, it is time to

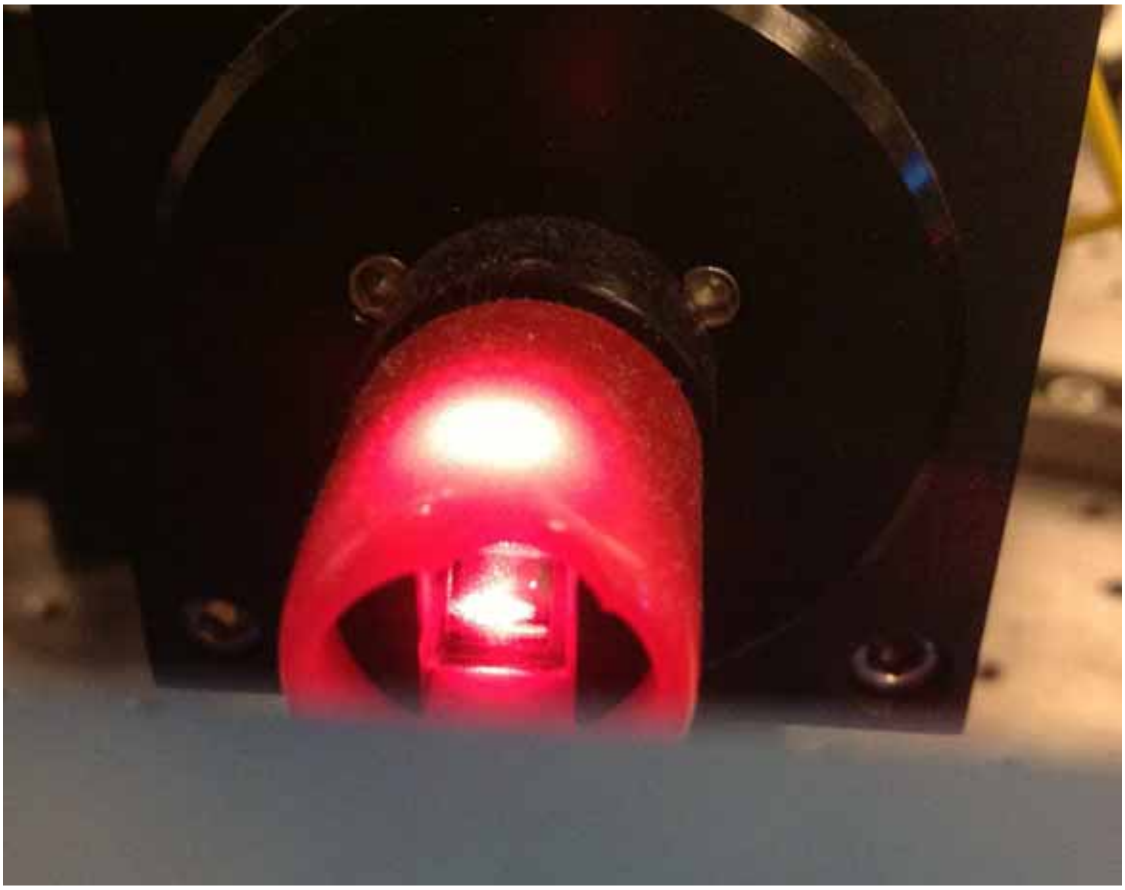
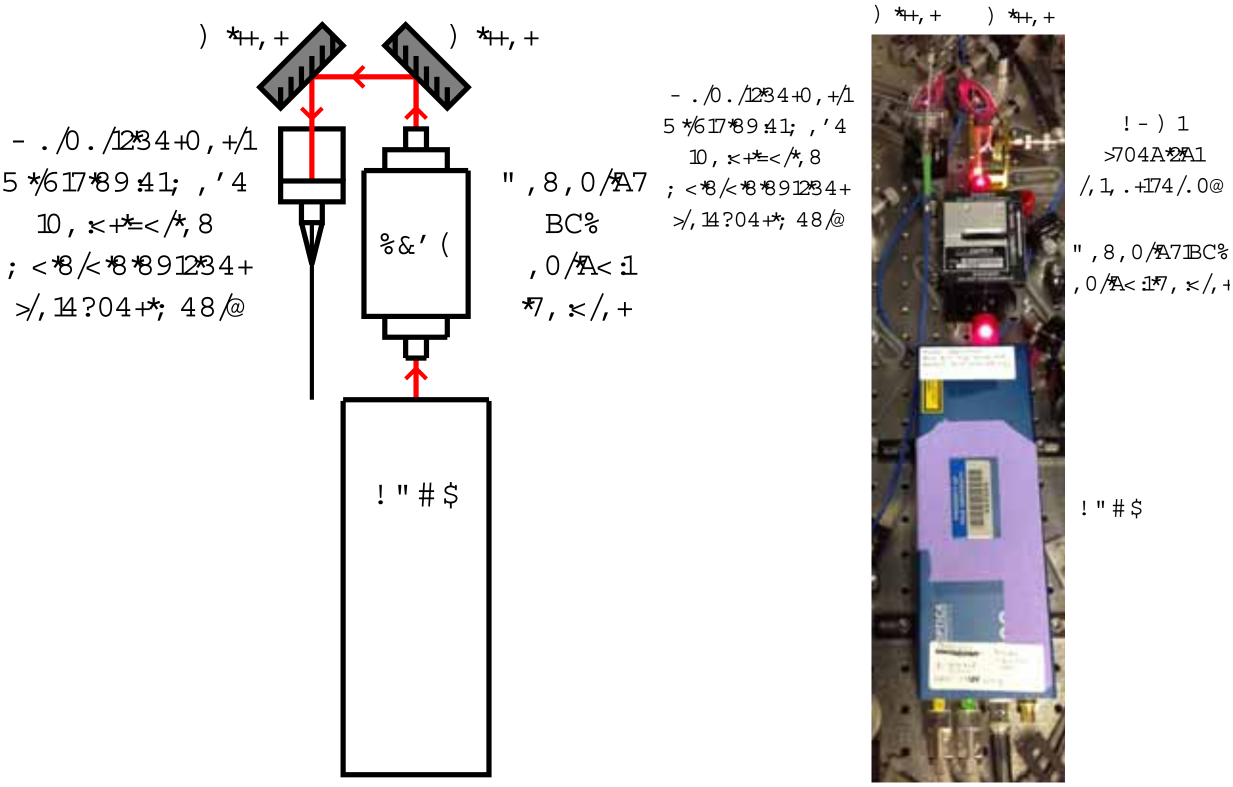


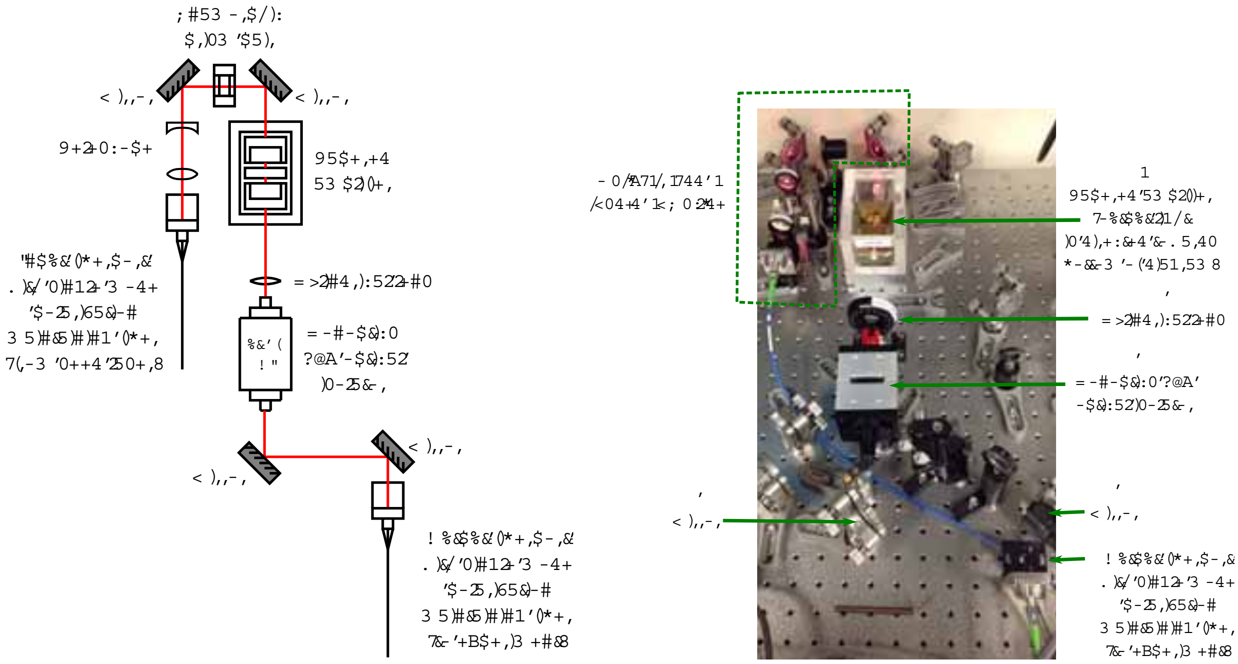
Figure 2: Centering the laser on the input of the isolator



(a) (b)

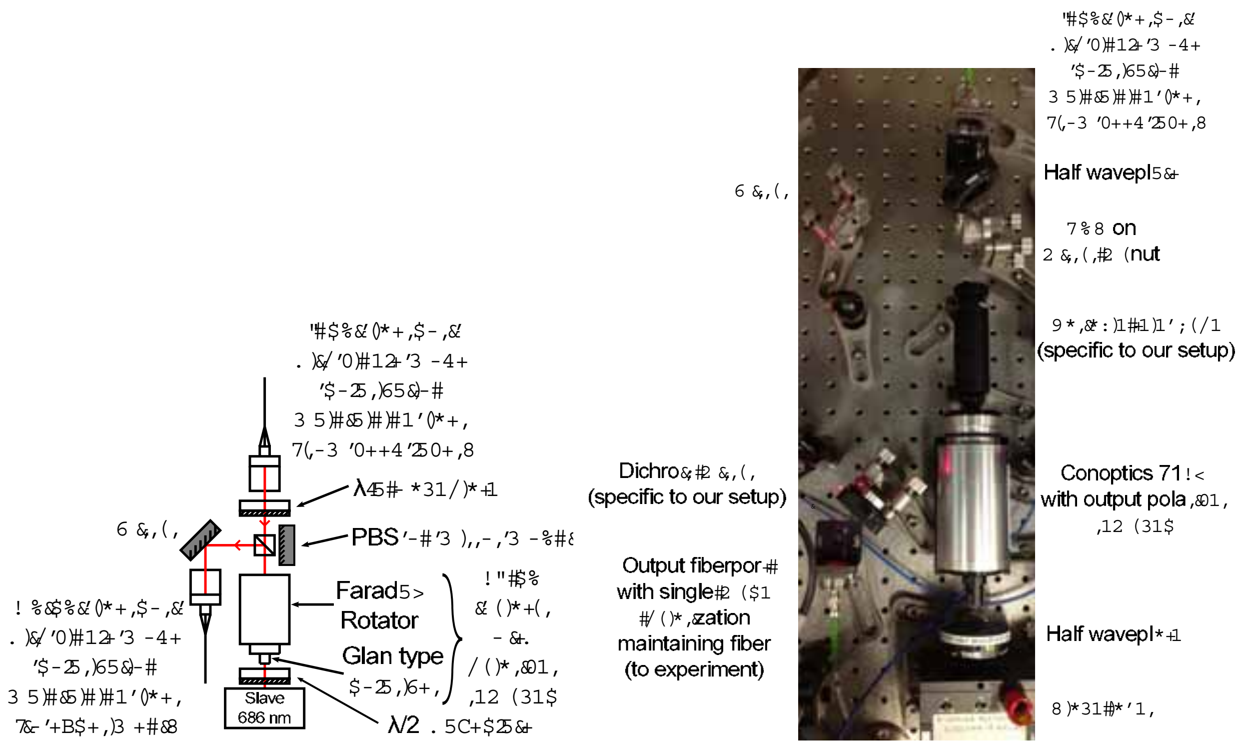
Figure 3: A typical implementation of a Conoptics 716 optical isolator into a setup for an ECDL.

roughly adjust the isolation of the optical isolator. Rough adjustment of the isolation is typically done by turning the adjustment knob to maximize the transmission of the laser through the isolator. After this is done, we verify that we are achieving the specified transmission for the isolator, which is usually $\approx 90\%$. Transmission values significantly lower than this usually indicate that the laser beam is being clipped while passing through the isolator. Fine adjustment of the isolation, if found to be necessary, it typically left until the laser system has been set up completely. Further diagrams and pictures of our overall laser setup including the optical isolator are as follows: Fig. 3 depicts an ECDL setup, Fig. 4 depicts a tapered amplifier setup, and Fig. 5 depicts a slave laser setup.



(a) (b)

Figure 4: A typical implementation of a Conoptics 716 optical isolator into a optics setup for a tapered amplifier.



(a) (b)

Figure 5: A typical implementation of a Conoptics 716 optical isolator into a slave laser setup.

4 Maximizing Isolation

As described earlier, we roughly set the isolator by simply tuning the adjustable knob to maximize transmission through the isolator. If the isolator is being used for a wavelength for which it is designed, the points of maximal transmission and maximal isolation should occur near simultaneously. Sometimes the above is enough to sufficiently isolate the laser from any backreflections. Other times doing so is insufficient and more involved procedures are necessary. The first step is to determine whether a given laser is suffering from optical feedback, which usually manifests itself as frequency instability. The frequency stability of a laser can be evaluated by looking at the laser on a Fabry Perot.

If a given laser is suspected to be suffering from unwanted optical feedback, an easy check is to put an neutral density filter (typically ND1.0 or similar) in between the laser and its optical isolator. If the unwanted optical feedback is coming from a reflection, the reflection will pass through the neutral density filter twice. In the case of a ND1.0 filter, this would add an extra 20 dB of temporary isolation to the laser. Obviously this is not a long term solution because it requires a significant reduction in usable laser power. If a laser is indeed suffering from optical feedback, we usually perform one of the two following steps to ensure that we are getting the full maximum isolation from our isolator.

4.1 Standard method to maximize isolation

This method is outlined in the documentation that comes with the Conoptics isolators. It involves turning the isolator around. The problem with turning the isolator around is that for this method to be most effective, the isolator must be turned around exactly. For Conoptics isolators with round profiles, this isn't too hard since the isolator can be unattached from its aluminum mount and mounted exactly backwards in the mount, thereby guaranteeing that the isolator has been turned around exactly (or nearly so). For the 716 isolator where there is no mount, turning the isolator around exactly is considerably harder. Thus we have developed an alternative method to maximize the isolation for the Conoptics 716 optical isolators. Unfortunately our method requires a few more pieces of equipment than does the standard method and may not be possible for all labs.

4.2 Preferred method to maximize isolation (for us)

Our preferred method for maximizing the isolation from an optical isolator requires two lasers (hereon referred to as laser A and laser B) of the same wavelength to both be aligned into single mode polarization maintaining fibers. The setup for our method is shown diagrammatically in Fig. 6. Assuming you want to maximize the isolation of laser A's isolator, the procedure is as follows:

1. Turn off laser A. This is to prevent damage since we will be purposely sending a large amount of light backwards towards laser A through the laser A isolator.

2. Plug the end of the fiber from laser A into the laser B output fiberport. This will align light from laser B through the fiber exactly towards the laser A.

3. Either by eye (which typically requires the room to be dark) or using a photodiode placed between laser A and its isolator, turn the knob which adjusts the isolation to minimize the light which goes backwards through laser A's isolator. Assuming 100 mW light is propagating backwards, when tuned properly a 60 dB isolator will allow only 100 nW of light to reach the master laser.

We prefer the above method to maximize the isolation since that method does not require moving the isolator or turning the isolator around.

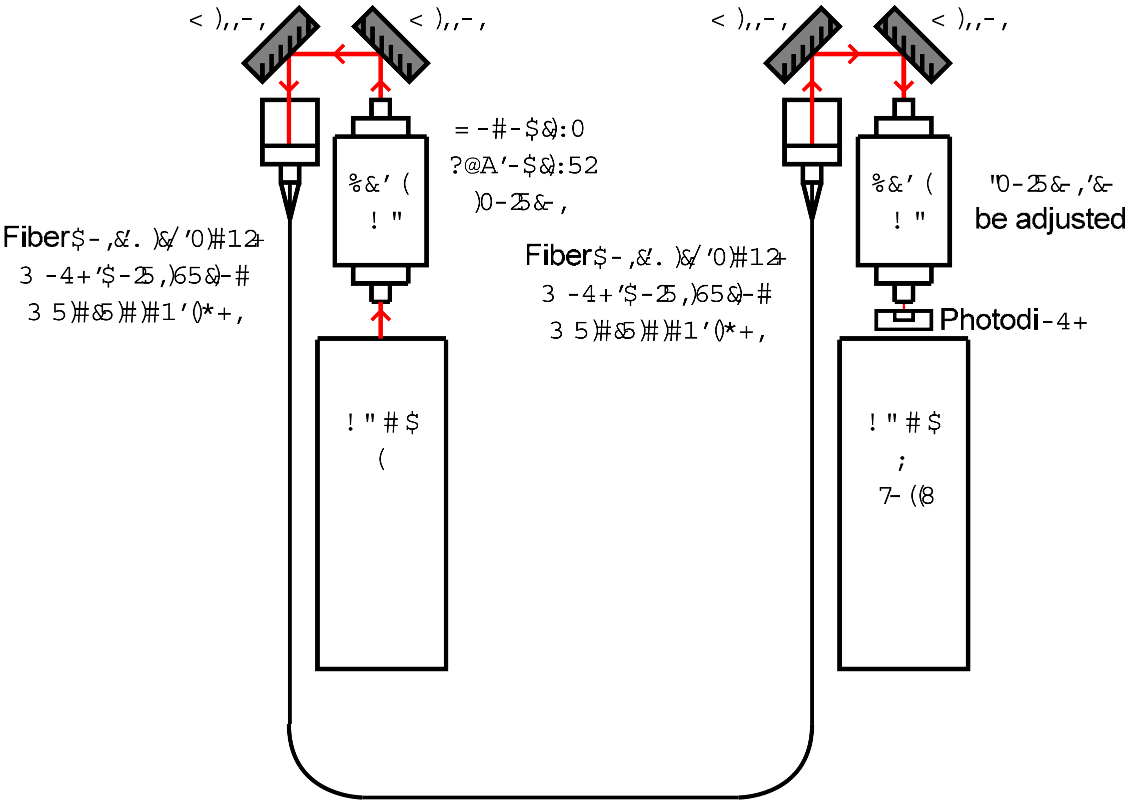


Figure 6: Our prefered setup for tuning the laser A isolator to achieve maximal isolation.