

Optical Fiber/Laser System for In Vivo (Multicolor) Light Delivery for Brain Neuromodulation V5.0

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NOTE: This white paper gives a parts list and step-by-step instructions for building an inexpensive and powerful laser-coupled-fiber system for in vivo use. It was compiled by Jake Bernstein and Ed Boyden, as an expanded version of the system described in **Figure 3** of the paper:

Bernstein, J. G., Han, X., Henninger, M. A., Ko, E. Y., Qian, X., Franzesi, G. T., McConnell, J. P., Stern, P., Desimone, R., and Boyden, E. S. (2008) Prosthetic systems for therapeutic optical activation and silencing of genetically-targeted neurons. *Proc Soc Photo Opt Instrum Eng*, 2008. 6854: p. 68540H. PMID: PMC2366937.

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Please note, part numbers for products are liable to change at any time; contact the manufacturer for updates, and please notify the authors of this white paper as well. Feedback always welcome!

0. Introduction

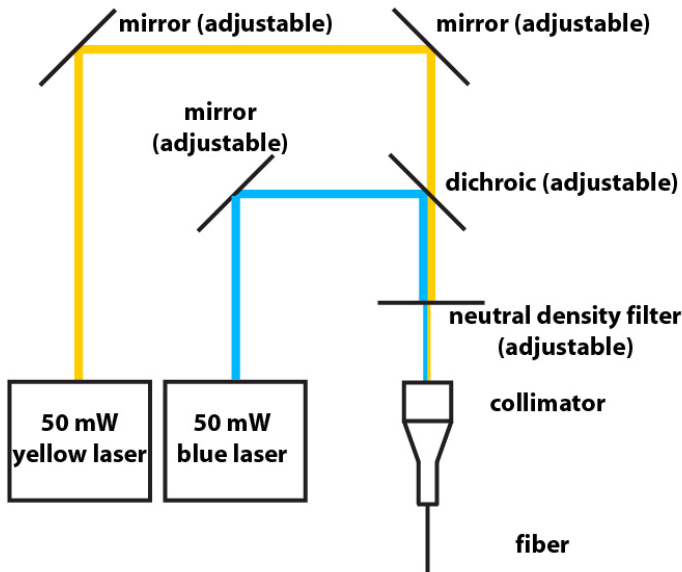
This two-laser, one fiber system is optimal for doing utilization of the blue-light activator channelrhodopsin-2 and/or the yellow-light inhibitor halorhodopsin (and future derivatives thereof) at the same time. In this way, bi-directional control of a single point in the brain can be performed, using ‘optogenetics’ technologies. This setups saves thousands of dollars, and is more flexible and powerful, than commercial single-color fiber-coupled lasers. In addition, the setup can be used (carefully) in an MRI-compatible fashion.

It is also appropriate for using halorhodopsin with blue-light resetting, which prevents run-down with extended illumination of halorhodopsin with yellow light, as demonstrated in **Figure 5** of

Han, X. and Boyden, E. S., Multiple-color optical activation, silencing, and desynchronization of neural activity, with single-spike temporal resolution. *PLoS ONE*, 2007. 2(3): p. e299. PMID: PMC1808431.

In general, multiple colors of light will increasingly be useful for driving multiple biological activities simultaneously.

1. Schematic:



2. Lasers are from Shanghai Dream Laser:

Tel: +86-21-37601510
 Fax: +86-21-57600170
 www.dreamlasers.com
 sales@dreamlasers.com

DPSS 593nm Orange laser
 TTL modulation at 10 kHz
 50mW
 SDL-593-050T

DPSS 473nm Blue Lasers
 TTL modulation at 10 kHz
 50mW
 SDL-473-050T

NOTE: Shanghai Dream Laser lasers are inexpensive, but if you pulse them, the power will depend on the pulse duration (e.g., the laser takes time to ramp up, and that makes short pulses weaker than longer pulses). Accordingly, it is important to characterize the power as a function of pulse duration and pulse repetition rate.

3. From Thorlabs:

Three **mirrors** - BB1-E02 1" Diameter Broadband Dielectric Mirror, 400-750 nm
 Two of the mirrors help steer the two beams into the fiber (see schematic above).
 The other two mirrors can be placed, one each, in front of the lasers, to facilitate alignment.

Four **mirror mounts** - KM100 Kinematic mirror mount for 1 inch optics
 Mount the mirrors and the dichroic (see below, from Chroma) on the kinematic mirror mounts.
 It is necessary to mount the dichroic, which does not fit in the 1" optics mount, by attaching it to a corner of the mount with double sided sticky tape or a drop of super glue.

Collimator is made out of:

- a. Collimator – F240SMA-A 8.0mm focal length SMA Fiber Collimation Pkg
- b. Adapter – AD12F - SM1 Adapter for Ø12 mm Collimators
- c. Lens tube - SM1L10 Lens Tube, ø1", 1" Long
- d. Lens tube mount - KM100T Kinematic mount for 1" optics

Optical fiber –we use .48NA optical fiber - BFH48-200.

- a. Tool to strip the coating - T12S21 – Fiber stripping tool (Clad/Coat: 250/500µm),
- b. Tool to cleave the fiber – S90W – Diamond wedge scribe
- c. Illustrated cleaving instructions – FN96A – Guide to Connectorization and Polishing of Optical Fibers

We do not polish the end of the fiber which interfaces with the brain after cleaving because cleaving suffices for making a very smooth optical surface (with some practice).

Optical Power Meter: PM100D – Power meter console

S121C – Photodiode sensor, 500nW-500mW range. The S121C is a good general-purpose photodiode. Although it is not ideal for measuring power output from optical fibers because the beam diverges, you can get a very close estimate to the total power output by holding the end of the optical fiber right in front of the center of the photodiode.

Neutral Density Filter - NDC-50C-2M Mounted Continuously Variable ND Filter, D:0-2.0

The neutral density filter wheel enables easy control of the output power of the optical fiber, since you normally want to shine less light on the brain than the lasers can output.

You'll need assorted posts and post holders (best to buy a kit with various heights), and a breadboard (say, at least 2 feet by 1 foot, with 1"-spaced holes) to hold everything. You may also, depending on the laser models you use, want to use sheets of aluminum to raise the lasers up to the same height, to simplify the mirror tuning.

4. From Chroma:

Dichroic filter – a sharply-tuned GFP dichroic filter will do (e.g., reflects blue, passes yellow).

Note: The laser beam is small; a single dichroic filter can be cut into multiple pieces if desired.

5. From oceanoptics.com:

Fiber termination kit - TERM-KIT – so you can put an SMA connector on the end, to fit in the Fiber adapter above. See <http://www.oceanoptics.com/products/fiberkits.asp#termination>

6. Laser Safety:

The class IIIb lasers recommended in this paper can cause blindness if improperly operated. Your institution may also offer classes on laser safety. Regardless, when setting up a laser system for the first

time, it is best to enlist the help of an expert. Handling, cleaning, and aligning optics are laboratory skills that must be learned hands-on.

7. Alignment Tips:

Couple the blue laser to the fiber first. Then couple the yellow laser by aligning it to the same path as the blue beam after the dichroic. Insert a sheer piece of lens cleaning paper into the beam path to visualize the location of the blue and yellow beams. Manipulate the two mirrors on the yellow beam path before the dichroic such that the blue and yellow beams are coincident just after the dichroic and just before the collimator.