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- LIGO -
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Advanced LIGO Output Mode Cleaner Diode Alignment

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1 Introduction

The alignment of the eLIGO OMC diodes left something to be desired. A few particular failings stood out:

- the diode chips were off-center with respect to the diode can preventing easy mechanical alignment and requirement a larger adjustment range;
- the diode position was adjusted within an inadequate $\pm 1\ mm$ using the slop in the oversized mounting;
- the diode mounting required four difficult to use screws and access to both sides of the diode;
- and because of the above, the diodes were difficult to replace.

The new diode mounting scheme described in §2 (an eDrawing can be found in [1]) is meant to overcome these failings and provide an easy to use, precise, and interchangeable diode mounting by separating the tasks of aligning a diode to the laser, and aligning diodes to each other. This note describes the diode mounting and alignment procedure.

TLAs

eLIGO Enhanced LIGO

OMC Output Mode Cleaner

QPD Quadrant Photo-Diodes

References

[1] *aLIGO Output Mode Cleaner Diode Mount Assembly;* D110208

[2] *Advanced LIGO Output Mode Cleaner Assembly;* D1101965

[3] *Advanced LIGO Output Mode Cleaner Diode Alignment Assembly;* D1102339

2 Diode mounting assembly

As shown in Figure 1, the diode mount consists of two functional units: a base and a carrier. The base is aligned to the laser beam and permanently attached to the OMC. The photodiode is aligned and permanently attached to the carrier. The carrier and base are aligned to each other using shoulder bolts. This two-part assembly separates the one-time step of aligning the diode to the incident laser from the (possibly) repeated task of aligning a large number of interchangeable diodes. This assembly method will also be used for the QPDs.

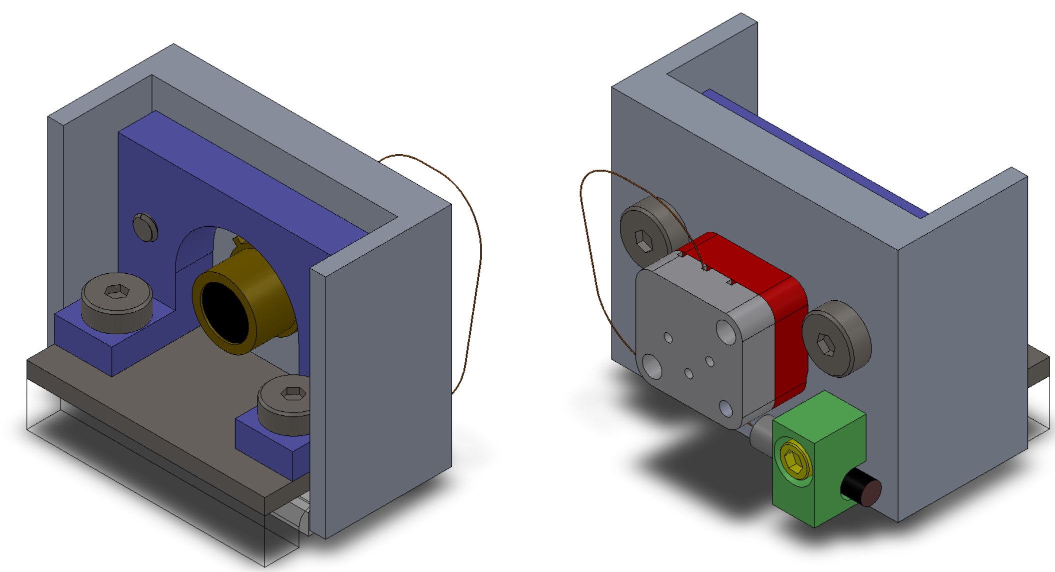

Figure 1: The diode mounting assembly consists of a glass block attached to the OMC, a pre-aligned base, and a carrier. The *base* (dark blue) is attached to a glass mounting block (clear) using two shoulder bolts, a barely visible peek nut plate, and an shim (dark grey). The diode (gold) is permanently attached to the U-shaped *carrier* (light grey). The carrier is then aligned and attached to the base with shoulder bolts. The cable connects to the diode with a PEEK connector (red and grey) and the cable is strain reliefed (green).

2.1 Carrier

The carrier serves two purposes: 1. it radiates the heat generated in the photodiode, and 2. it provides a mechanical alignment reference for the diodes. There are three variation of the carrier shown in Figure 2 that rely on machining precision for their relative alignment.

Each carrier includes oversized clearance holes for the photodiode pins, a hole and slot for mounting and alignment, and two 2-56 threaded mounting holes for the cable strain relief. The alignment target has a Thorlabs VRC2D05 fluorescent alignment disk bonded to the center. The VRC2D05 has a 1.5 mm hole in the center, and the alignment carrier has an even smaller 0.8 mm hole to aid in alignment. These should allow repeatable alignments to $\approx 0.1\ mm$, much smaller than the incident $0.5\ mm$ waist size. The diodes and alignment disk will be permanently glued to the carrier using the electrically insulating, thermally conductive Tra-Bond #2151 epoxy.

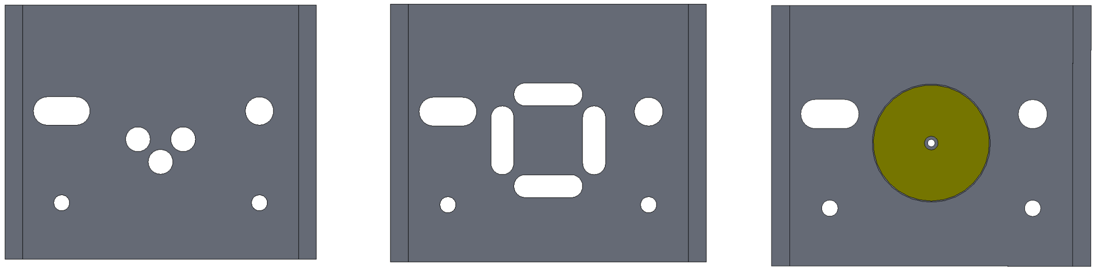

Figure 2: Front view of the diode carrier. Three variations of the carrier are used for the 3 mm E.G.&G. photodiode, the OSI Q3000 QPD, and a Thorlabs VRC2D05 alignment disk. The disk is shown in yellow, glued into a pre-defined location.

The carrier must be sized to radiate the heat generated in each photo-diode. We assume the diode has a 3 V bias, 30 mW of incident light, and 25 mA of photocurrent. Together, this is a heat load of $dP \approx 100\ mW$. We assume this heat is dissipated radiatively, and the aluminum radiator is flame-sprayed with an alumina coating with emissivity $\epsilon = 0.9$. Using the Stefan-Boltzmann relation for a surface of area A, we find that

$$\begin{aligned} dP &= 4A\epsilon\sigma T^3 dT, \\ dT &= \frac{181}{A}\frac{C}{cm^2}. \end{aligned} \tag{1}$$

The carrier shown in Figure 2 has an *external* surface area of 18 cm^2, with a corresponding temperature rise of $dT = 10\ C$. Because the carrier will radiate from more than just the external surface, the temperature should be somewhat lower. The U-shape of the carrier increases the surface area and provides some measure of protection for the can-removed diodes.

2.2 Base connection

Figure 3 shows an exploded view of the connection between the aluminum diode base and the glass block. The connection includes a 2 mm shim plate to accomodate a $\pm 2\ mm$ uncertainty in the incident laser beam height. If thinner shims are used, washers under the bolts will be required to prevent the bolt from extending through the nut plate and into the OMC. The nut plate is made out of PEEK to allow for thermal expansion without excessively stressing the glass. The shoulder bolts are aligned to precision holes in the glass block, while the diode base is aligned to the shoulder bolts with a hole and slot system, providing repeatable alignment of the base to the glass.

2.3 Carrier connection

The carrier to base connection is shown in Figure 4. Once the base has been secured to the OMC, it is a matter of two bolts, accessible from the rear, to attach the diode. The hole and slot, together with the shoulder bolts, ensure the alignment of the diode. The cable can be

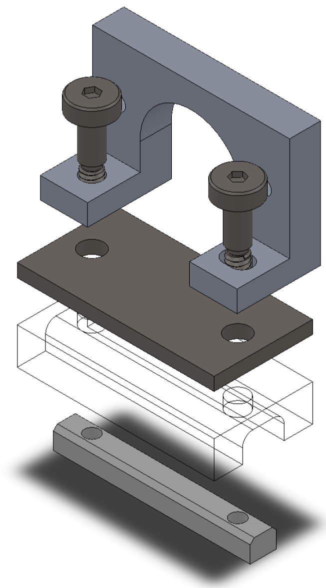

Figure 3: The diode base (grey), is attached to the U-shaped glass block (clear), using two standard shoulder bolts. The diode height is adjusted using a 2 mm shim (dark grey). Compliance is provided by a PEEK nut plate (whitish). The glass block is 30 mm long and 15 mm wide.

connected to the carrier before or after the carrier is mated to the base. The cable is shown here with ≈ 2 inches of slack for easy handling. In practice, it could have less slack.

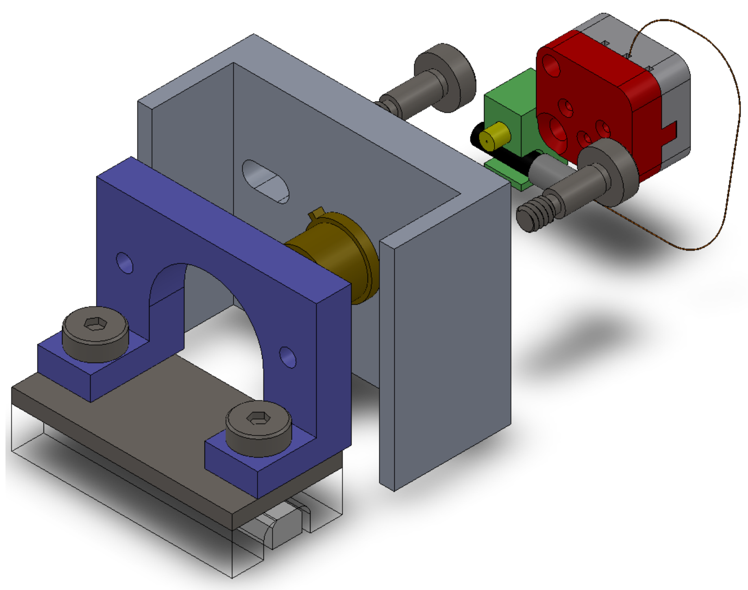

Figure 4: The carrier to base connection is accomplished with two shoulder bolts. The bolts provide alignment as well as holding the assembly together.

3 Alignment

There are two steps to the alignment. First is the alignment of the base to the laser beam on the OMC. Second is the alignement of the diode to the carrier.

3.1 Base to laser

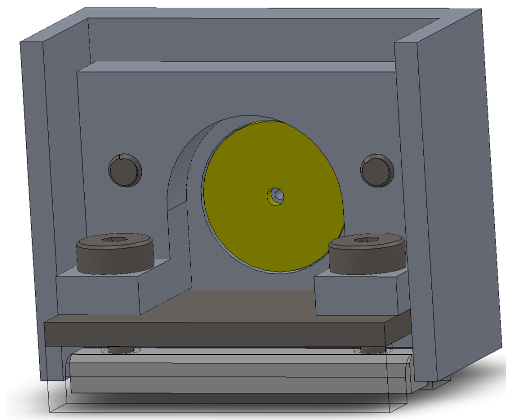

Figure 5: The alignment of the base to the laser is accomplished with the aid of the alignment carrier.

The first step of the base alignment is to set the base height correctly. The beam height is designed to be 15 mm above the OMC surface. The base assembly (Figures 3 and 5) includes a 2 mm spacer to adjust the height. The correct shim must be chosen to match the actual beam height and the difference compensated to keep the shoulder bolts engaged and avoiding interference. Once the height is chosen correctly, the alignment disk and carrier is mounted to the base as shown in Figure 5. The disk, together with the hole in the carrier, provide the alignment reference to correctly set the horizontal position of the glass block on the OMC. Once the base is properly aligned, the glass block is UV epoxied in place.

3.2 Diode to carrier

The diode alignment to the carrier makes use of an external alignment block. The block, shown in Figure 6, is made to be bolted to an optics table with 4 1/4-20 bolts. It has a clearance hole for the diode pins and alignment pins to set the position of the carrier. The carriers are positioned with respect to the alignment block using two dowel pins. (This could also be done with shoulder bolts.) The alignment carrier provides a reference for an external camera. By fixing the camera (or long-working distance microscope) with respect to the block, we construct a transfer reference that will allow alignment of each diode to its carrier. By using the alignment pins, the only dimension that matters is the centering with respect to the pins and the original alignment carrier.

We envision making up all of the diodes, both production and spare diodes, in one assembly session. For each OMC, there will be a set of production diodes and spares, for a total of 12 3 mm diodes and 12 QPDs.

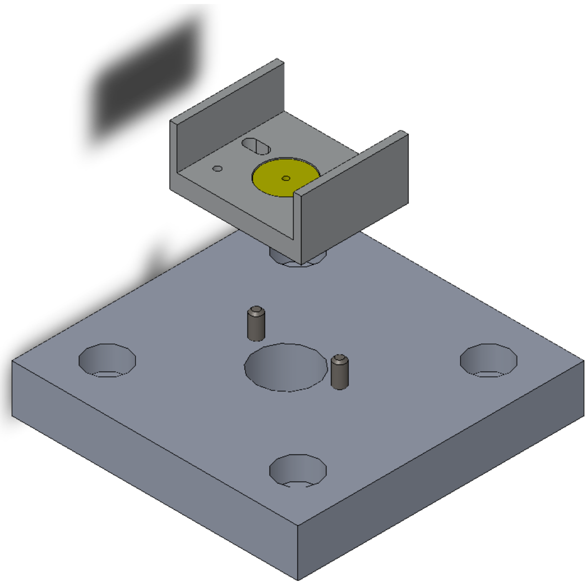

Figure 6: The diode alignment block bolts to a table and includes alignment pins to set the carrier position.

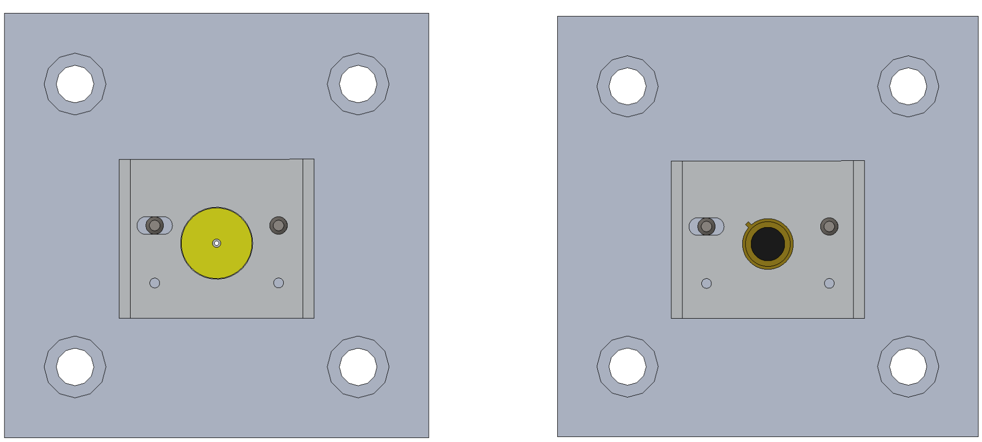

Figure 7: A view of two carriers mounted to the alignment block. The alignment disk (on the left) allows the positioning of a camera, which, remaining fixed, can in turn be used to position the diodes (on the right).

4 Conclusion

We have presented here a mechanical assembly and alignment scheme for mounting photodiodes to the Output Mode Cleaner. The system addresses the shortcomings of the eLIGO system described in §1, and should allow precise, repeatable, and interchangeable mounting of the OMC diodes.