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ETM Transmon Pupil Relay

Michael Smith

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This is an internal working note
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California Institute of Technology
LIGO Project – MS 18-34
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – NW17-161
175 Albany St
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
P.O. Box 1970
Mail Stop S9-02
Richland WA 99352
Phone 509-372-8106
Fax 509-372-8137

LIGO Livingston Observatory
P.O. Box 940
Livingston, LA 70754
Phone 225-686-3100
Fax 225-686-7189

http://www.ligo.caltech.edu/

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Abstract

The ETM Transmon Pupil Relay optical system forms an image of the ETM telescope entrance pupil onto the surface of the ETM Transmon QPD and minimizes the sensitivity of the Transmon QPD on the rotation of the suspended ETM Transmon table with its associated optics. The QPD height to ETM height transfer function is 12 microns/mm. The spot radius at QPD = 0.7 mm. The Requirements on the stabilization of ETM Transmon optical table are: tilt < +/- 0.01 deg; lateral displacement < 0.1 mm.

1 Introduction

The ETM Transmon Pupil Relay optical system forms an image of the ETM telescope entrance pupil onto the surface of the ETM Transmon QPD and minimizes the sensitivity of the Transmon QPD on the rotation of the suspended ETM Transmon table with its associated optics.

2 Analysis

2.1 Optical Layout

The optical layout of the ETM reflective off-axis parabolic telescope and the pupil relay optical system, which are mounted to the suspended ETM Transmon optical table, is shown in Figure 1.

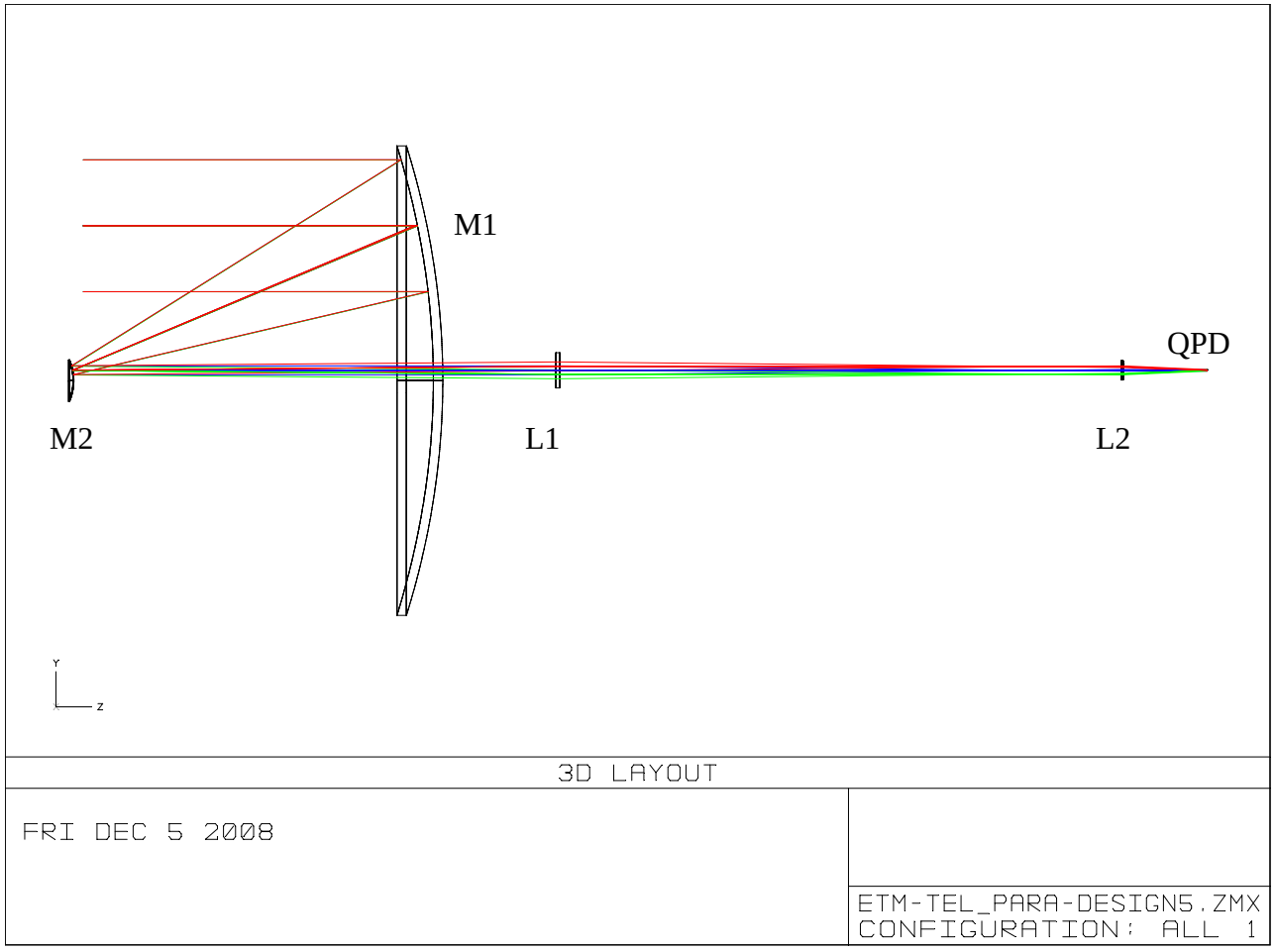

Figure 1: ETM Telescope and Pupil Relay Optical System

Mirrors M1 and M2 comprise a 15:1 beam reducing reflective telescope. Lenses L1 and L2 comprise a 5.7:1 beam reducing pupil relay optical system.

The telecentric afocal pupil relay forms a demagnified image of the aperture of M2 on the surface of the QPD. And since the reflective telescope also forms effectively an image of the ETM pupil onto the exit pupil of the ETM telescope, which is located approximately at M2, the entire optical system forms an image of the ETM telescope pupil onto the QPD.

The following stock CVI lenses were modeled for the Pupil Relay:

L1 PLCX-50.8-309.1-UV EFL = 687.5 mm

L2 PLCX-27.9-3.0-127.0-ZNSE EFL = 120.2 mm

Three sets of rays corresponding to three tilt angles of the ETM Transmon optical table are shown in Figure 2. The blue ray bundle is for zero tilt; the green rays are for -0.03 deg tilt; and the red rays are for 0.03 deg tilt. The effect of the pupil relay is to ensure that all three sets of ray bundles hit the QPD at approximately the same height, i.e. the QPD reading is relatively insensitive to the tilt of the Transmon optical table.

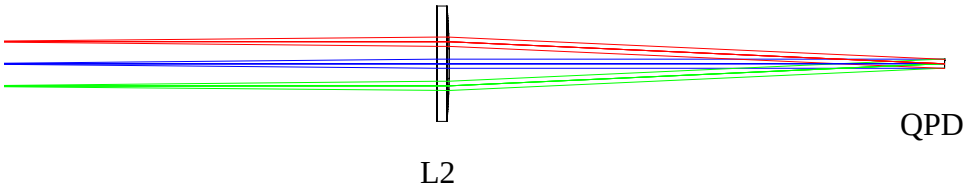

Figure 2: Beam Paths for Various Tilt Angles of the ETM Telescope/Pupil Relay System

2.2 Performance of the QPD Transmon Sensor

The height of the beam at the QPD in millimeters is a monotonic, approximately linear, function of the displacement on the ETM HR surface in millimeters for table tilt angles between -0.01 and 0.01 deg, as shown in Figure 3, where the red curve is for zero tilt; the dotted blue curve is for 0.01 deg tilt; and the green curve is for -0.01 deg tilt. These data were calculated using the ZEMAX geometric optics centroid position function.

Similar data is plotted in Figure 4 showing the change in the QPD spot height versus tilt angle up to 0.01 deg for various beam displacements on the ETM HR.

The QPD height to ETM height transfer function is 12 microns/mm.

From this data we can conclude that in order to measure absolutely a 1 mm beam displacement at the ETM HR surface, the suspended transmon optical table must be stabilized to within +/- 0.01 deg tilt, and the lateral displacement of the table must be < 0.1 mm.

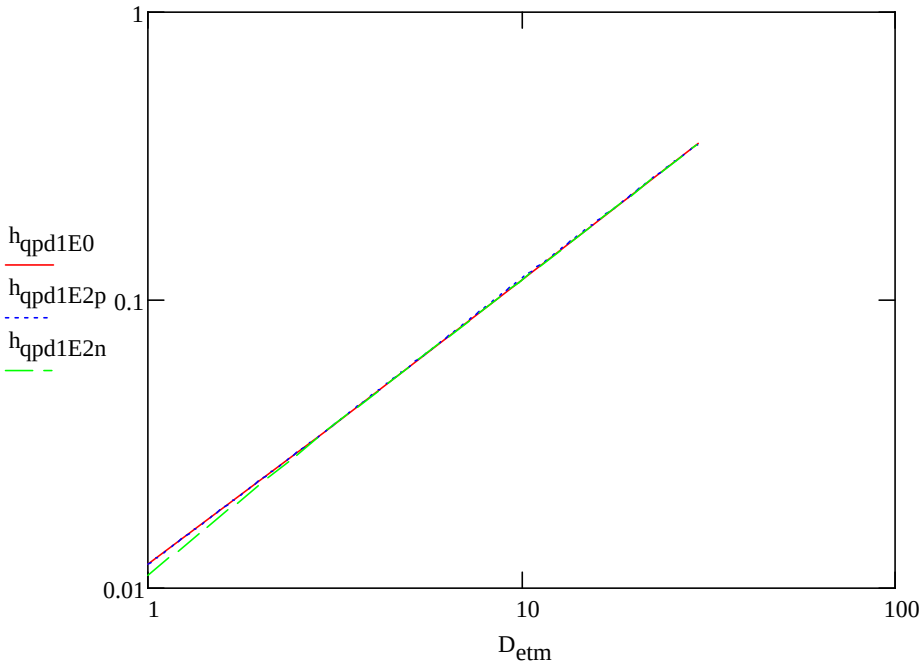

Figure 3: QPD Beam Height versus ETM Beam Height for Various Tilt Angles of the Optical Table

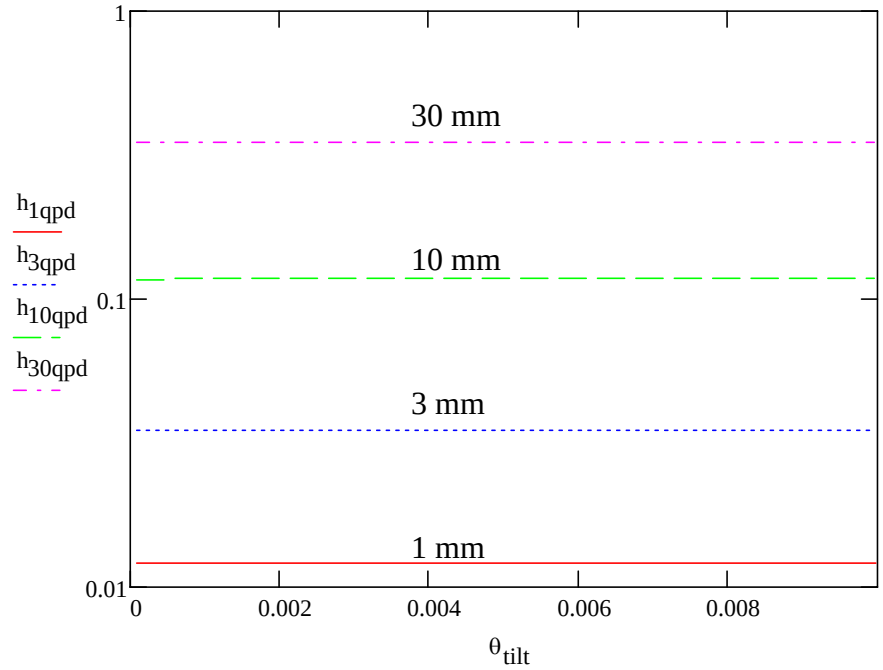

Figure 4: QPD Height versus Optical Table Tilt Angle, for Various ETM Beam Heights

2.3 Spot Size at the ETM Transmon QPD

The on-axis Gaussian spot profile on the ETM HR, with a 11.5 mm beam waist 2 km away, was calculated using the ZEMAX physical optics propagation program and is shown in Figure 5.

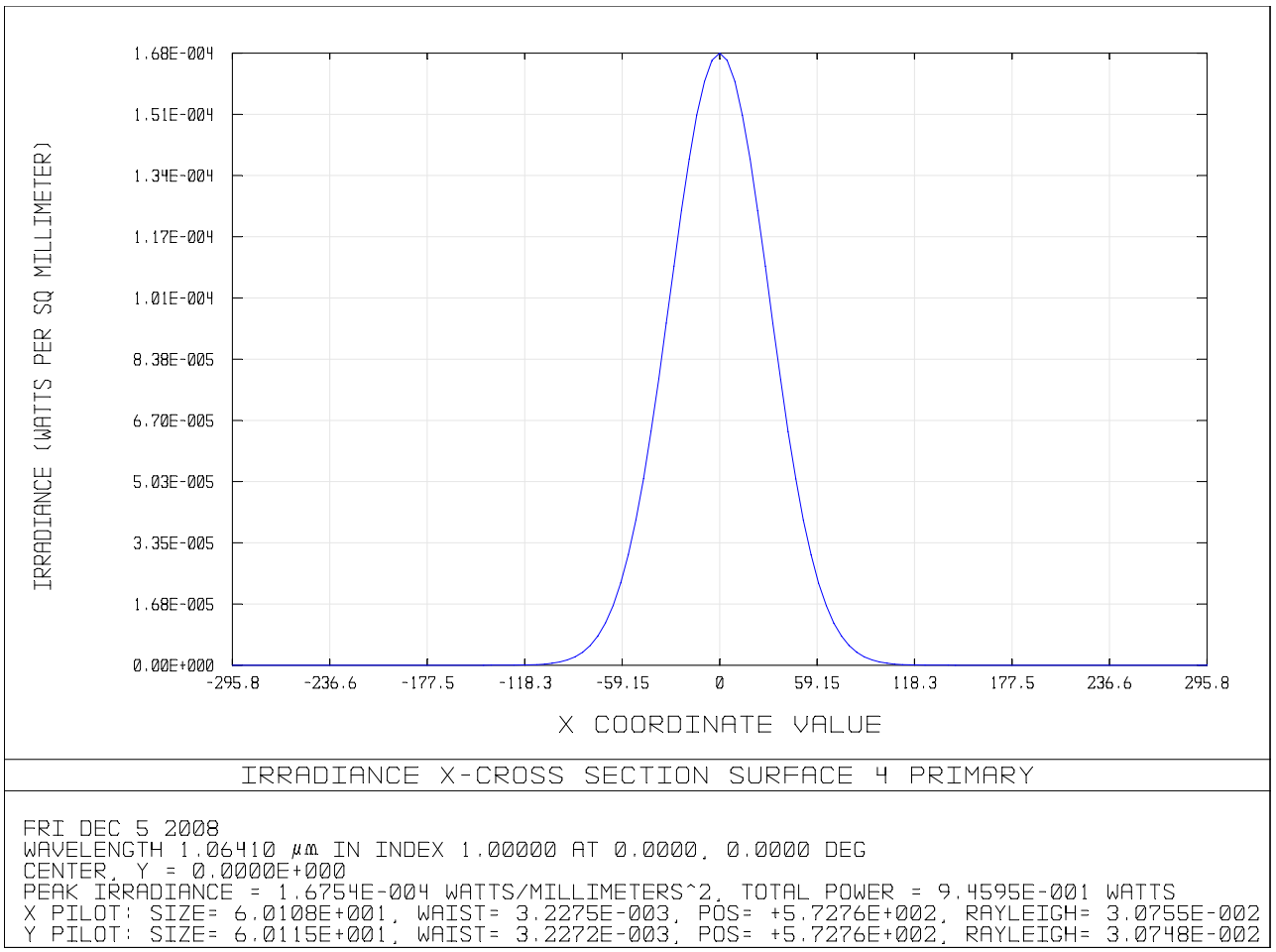

Figure 5: Gaussian Spot Profile at the ETM, mm

The Gaussian spot profile at the QPD is shown in Figure 6. The spot radius is approximately 0.7 mm.

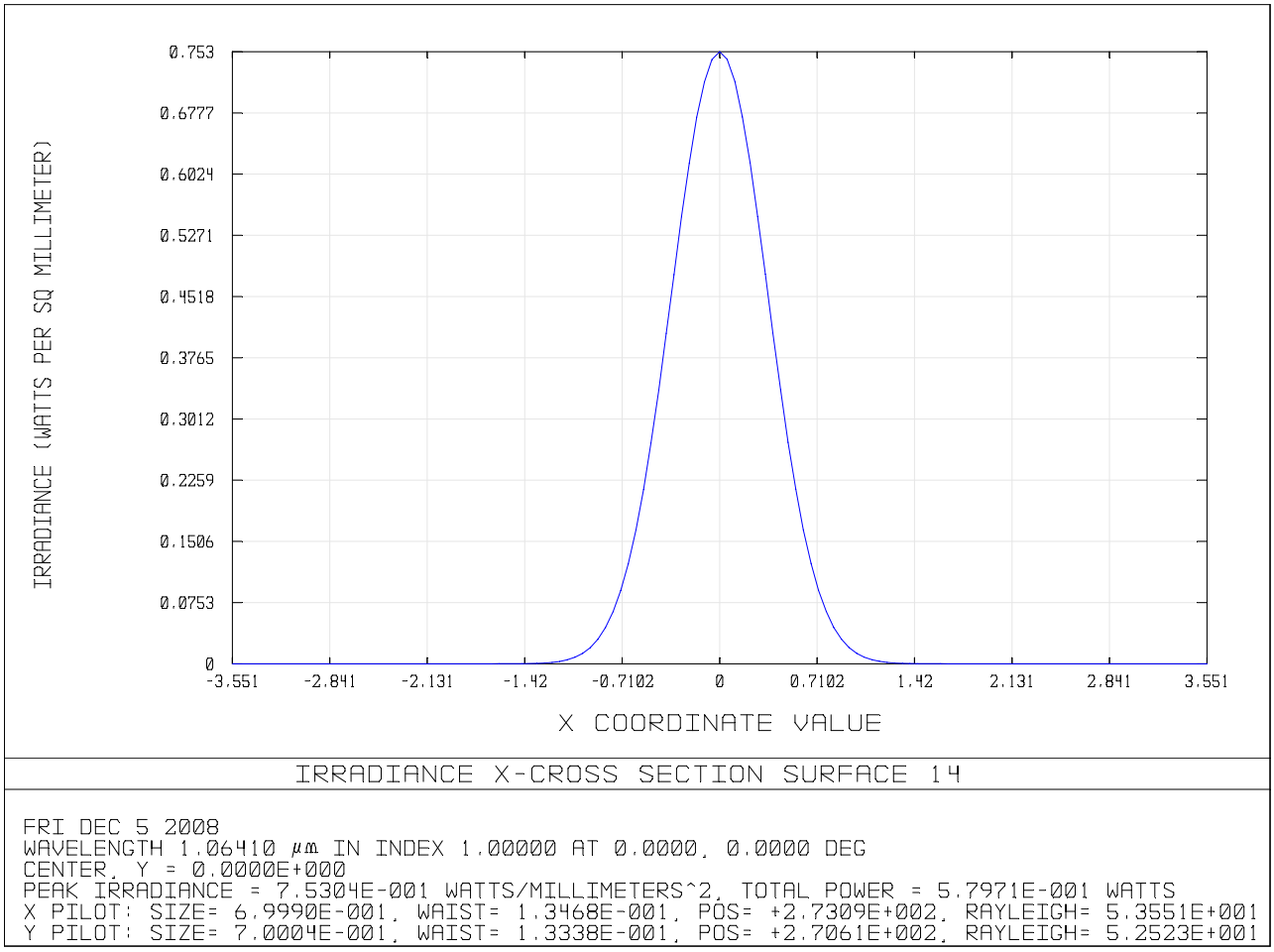

Figure 6: Gaussian Spot Profile at the QPD

3 Conclusion

The QPD height to ETM height transfer function is 12 microns/mm.

Spot radius at QPD = 0.7 mm

Requirements on the stabilization of ETM transmon optical table: tilt < +/- 0.01 deg; lateral displacement < 0.1 mm.