

# Optical multiplexer for laser phase locking

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## INTRODUCTION

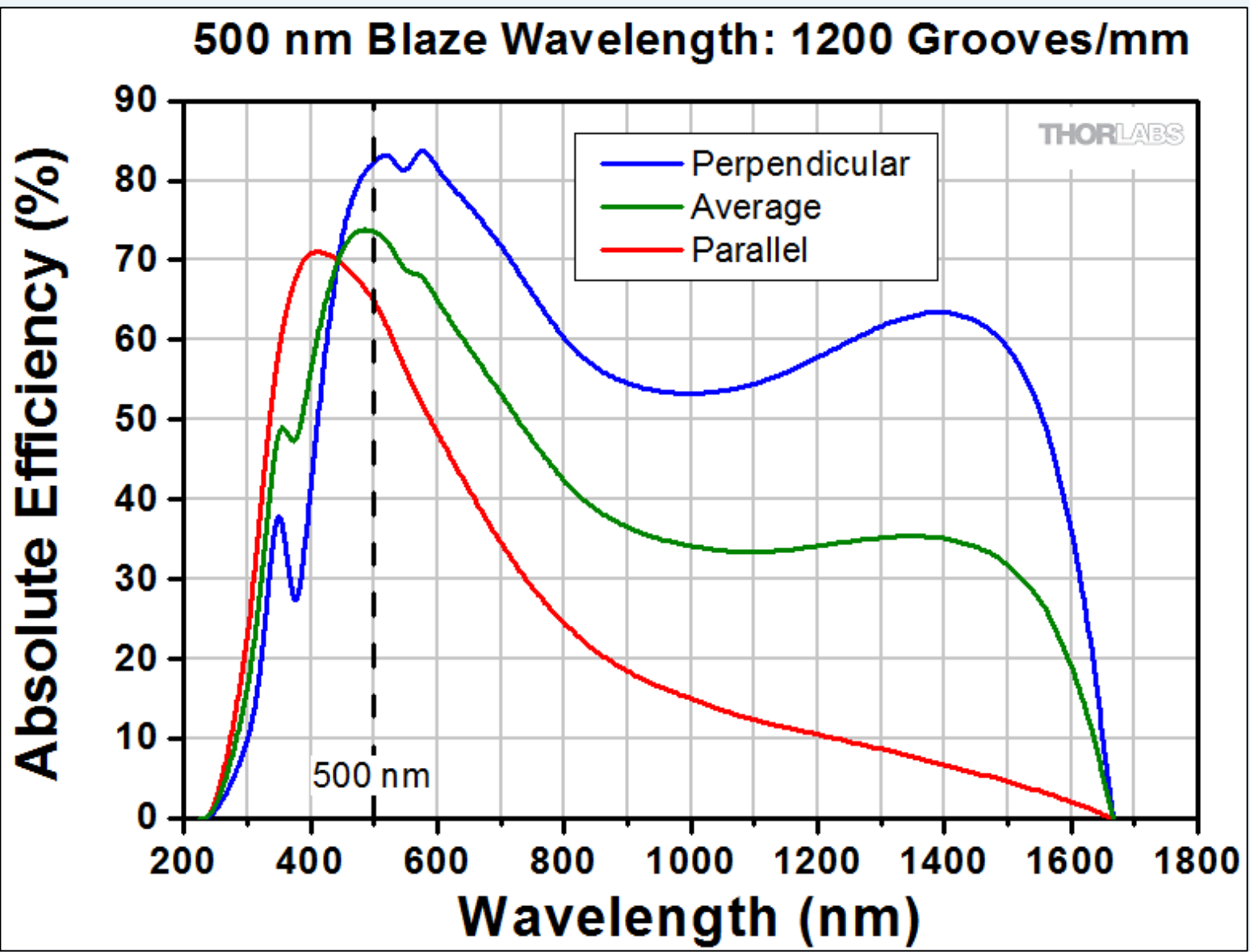
A self-referenced frequency comb allows for precise measurements of optical frequencies. This is done by generating repeated, short laser pulses. This creates frequencies that are evenly spaced in the frequency domain. The self referencing technique doubles a lower frequency of the comb to determine the exact frequencies generated by the comb <sup>[1]</sup>. Overlapping the frequency comb with a continuous wave laser produces a beating signal that can be used to phase lock the laser to a comb line. This has applications in quantum sensing using ultracold atomic gas. This procedure needs to be repeated four times to satisfy experimental requirements. However, a frequency comb is expensive, and the aim of this project is to create a device that can use a single frequency comb to perform the phase locking of four continuous wave lasers independently.

## CONCEPT

The four lasers are to be overlapped with the frequency comb, and serve as the input of the device. The input laser is to be dispersed using a diffraction grating. This is followed by a series of mirrors that fine tunes the target beams into optical fibres to allow further detection. This device has to be compact, and should be reversible to allow for the device to combine beams into a single fibre. The design should target four specified wavelengths that is experimentally produced. An enclosure is designed to contain the device, and also allow for FiberPorts to be mounted.

## DIFFRACTION GRATING

The diffraction grating used has 1200 lines per mm. This model was chosen as it provides good diffraction efficiency in the 600-700nm range as seen in the graph below.



Graph of GR13-1205 efficiency curve at Littrow Angle replicated from [2]

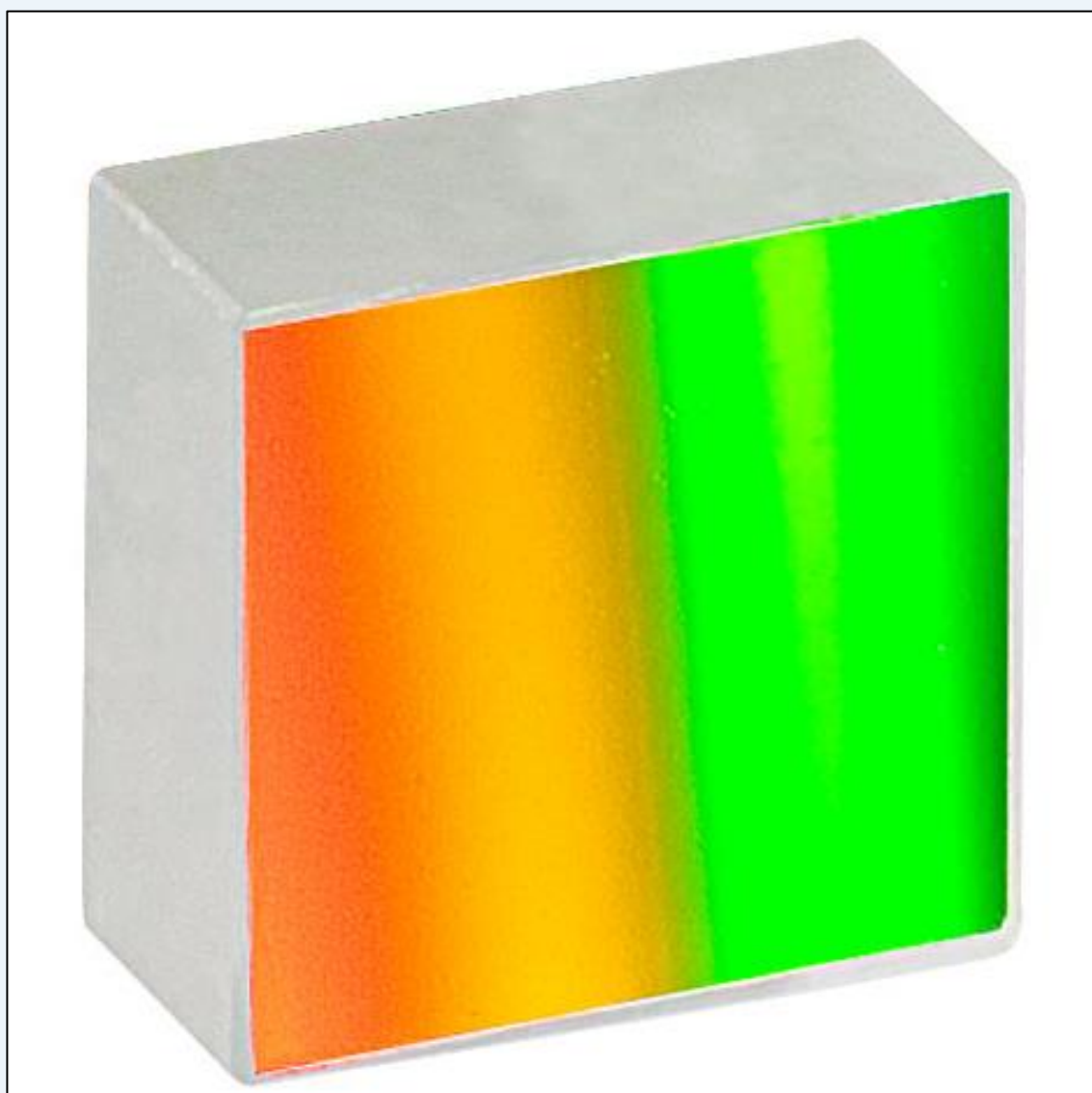
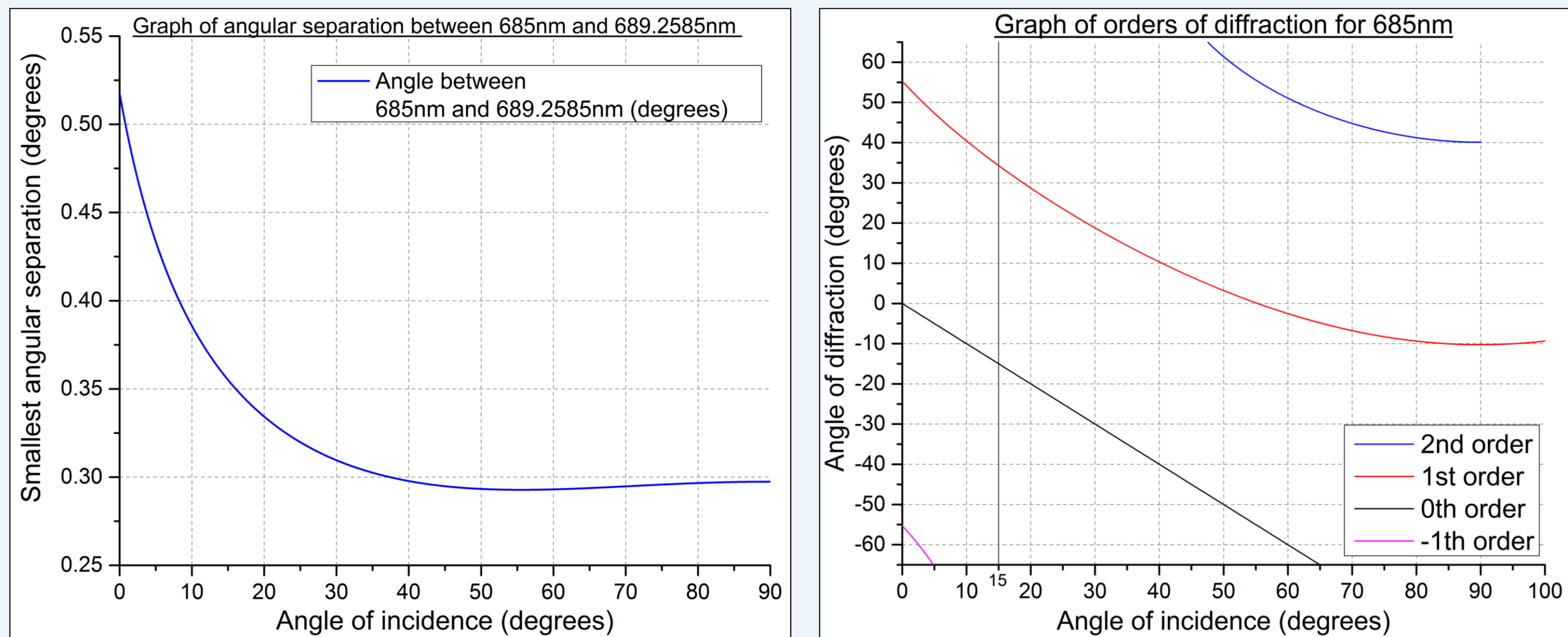


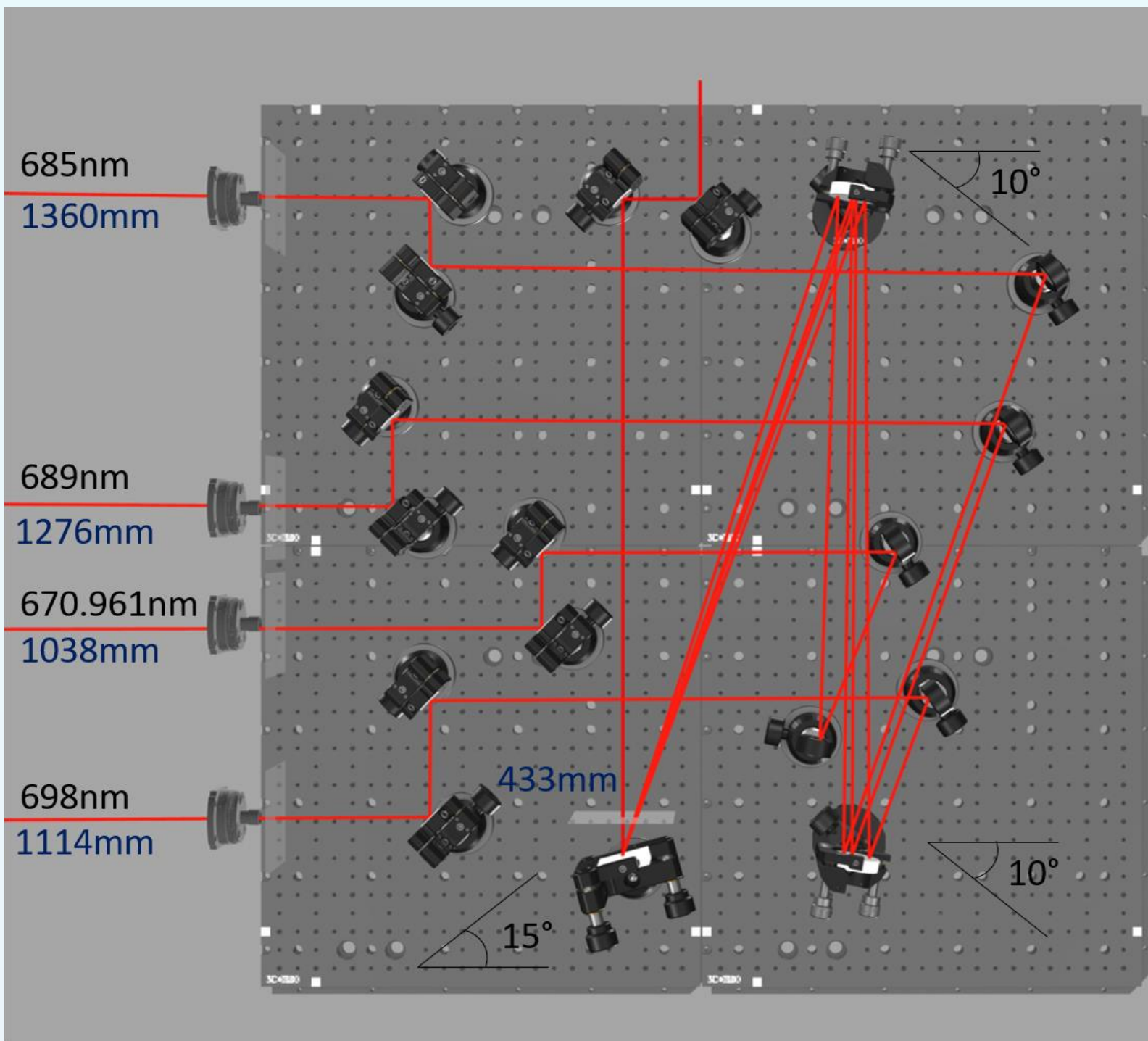
Figure of GR13-1205 Ruled Reflective Diffraction Grating taken from [3]

The angle of incidence on the diffraction grating has to be chosen to maximise the angular separation of the beams, while eliminating undesired non-zero orders. The graphs below explains the choice of the angle of incidence of 15°.

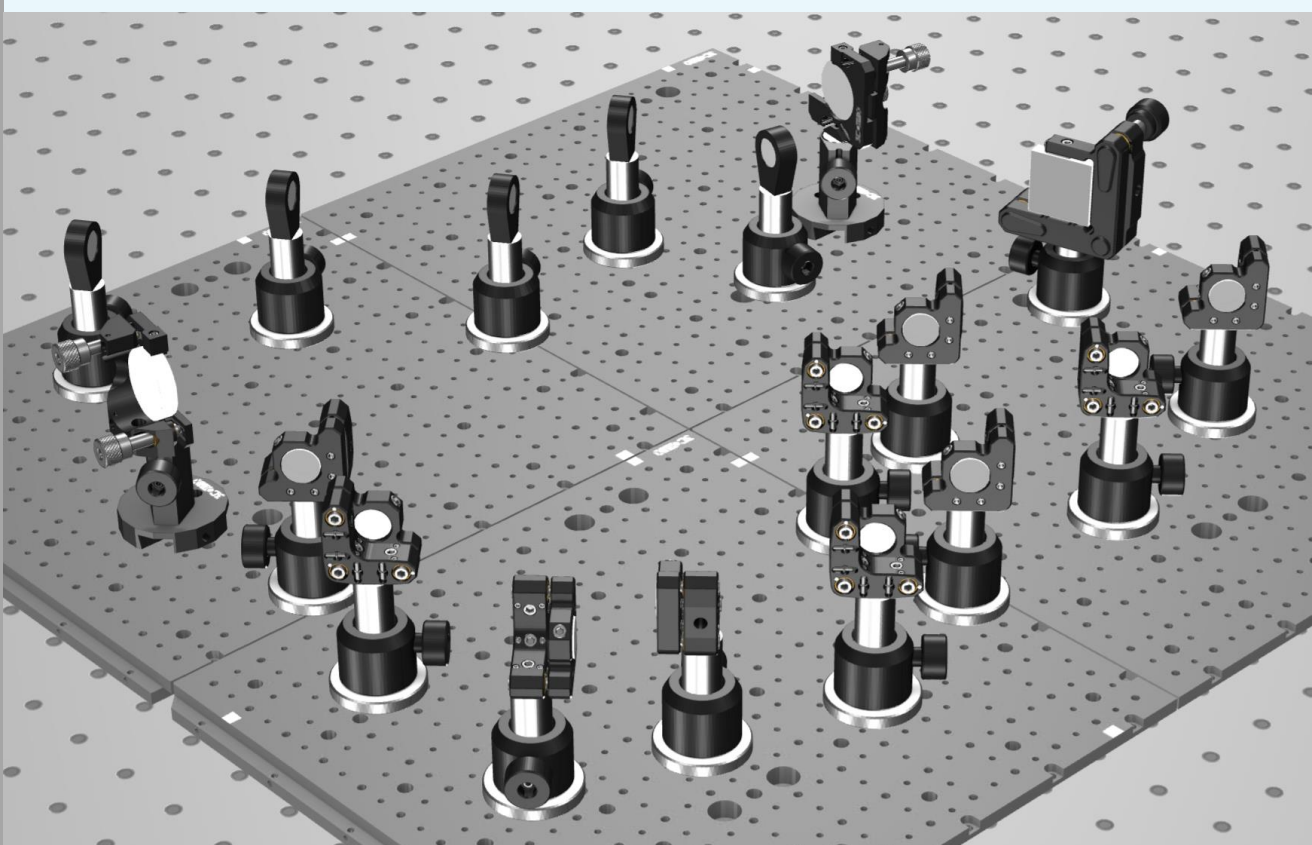


The graph on the left shows the smallest angular difference between two beams, which can be as small as ~0.3°, which proves to be a challenge to separate. The graph on the right depicts why 15° was chosen as the diffracted beam only contains beams of zeroth and first order, which is desired.

## 3DOptiX



3DOptiX<sup>[4]</sup> is an online ray optics software that simulates laser beams and allows for the optics to be drafted and simulated. The final draft simulation is illustrated.



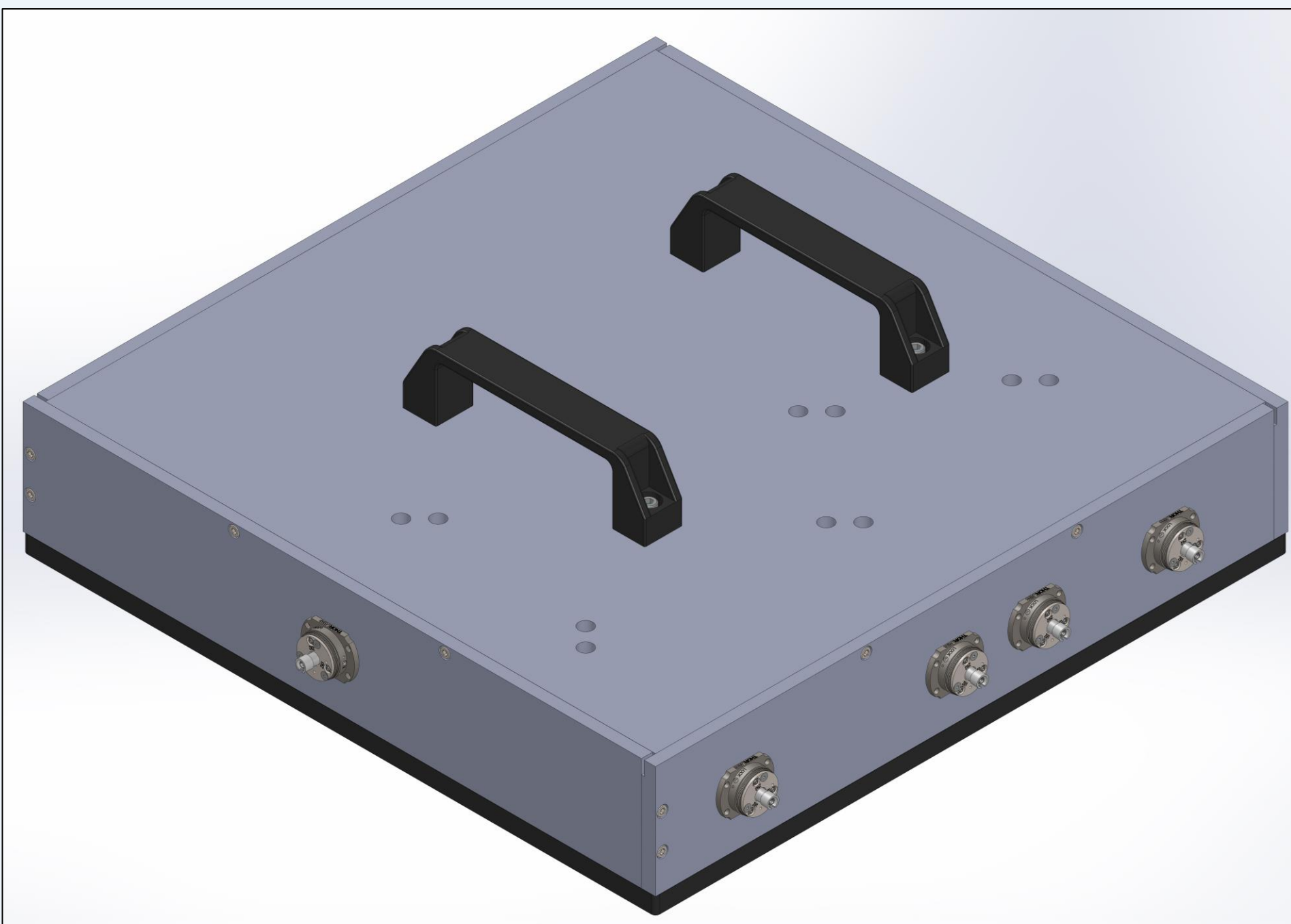
## BREADBOARD LAYOUT



SolidWorks was used to design and emulate the layout of the optics as planned in 3DOptiX, using CAD models of the actual components to be used.

The breadboard used is 45cm × 45cm to keep the design as compact as possible.

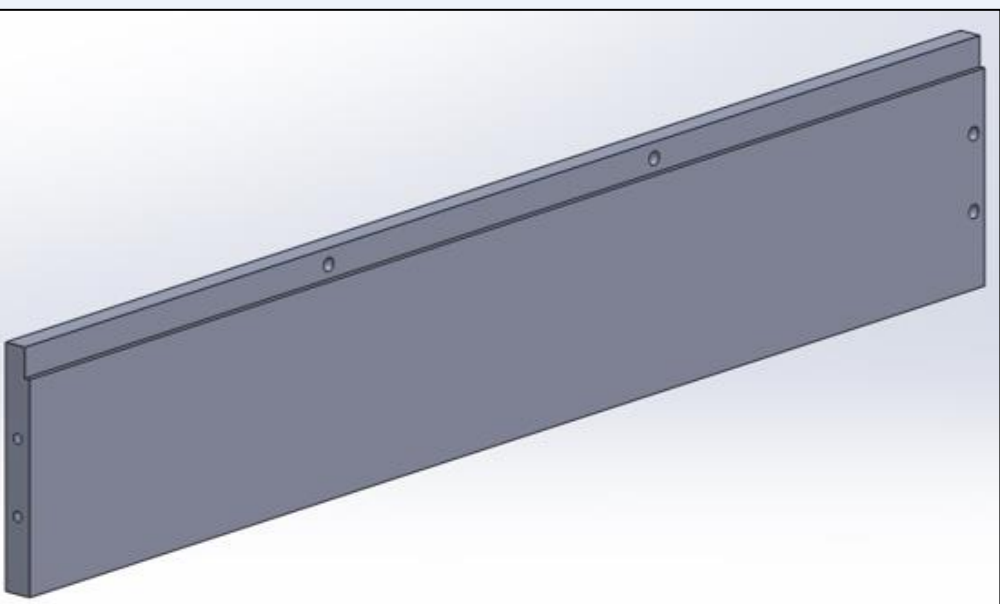
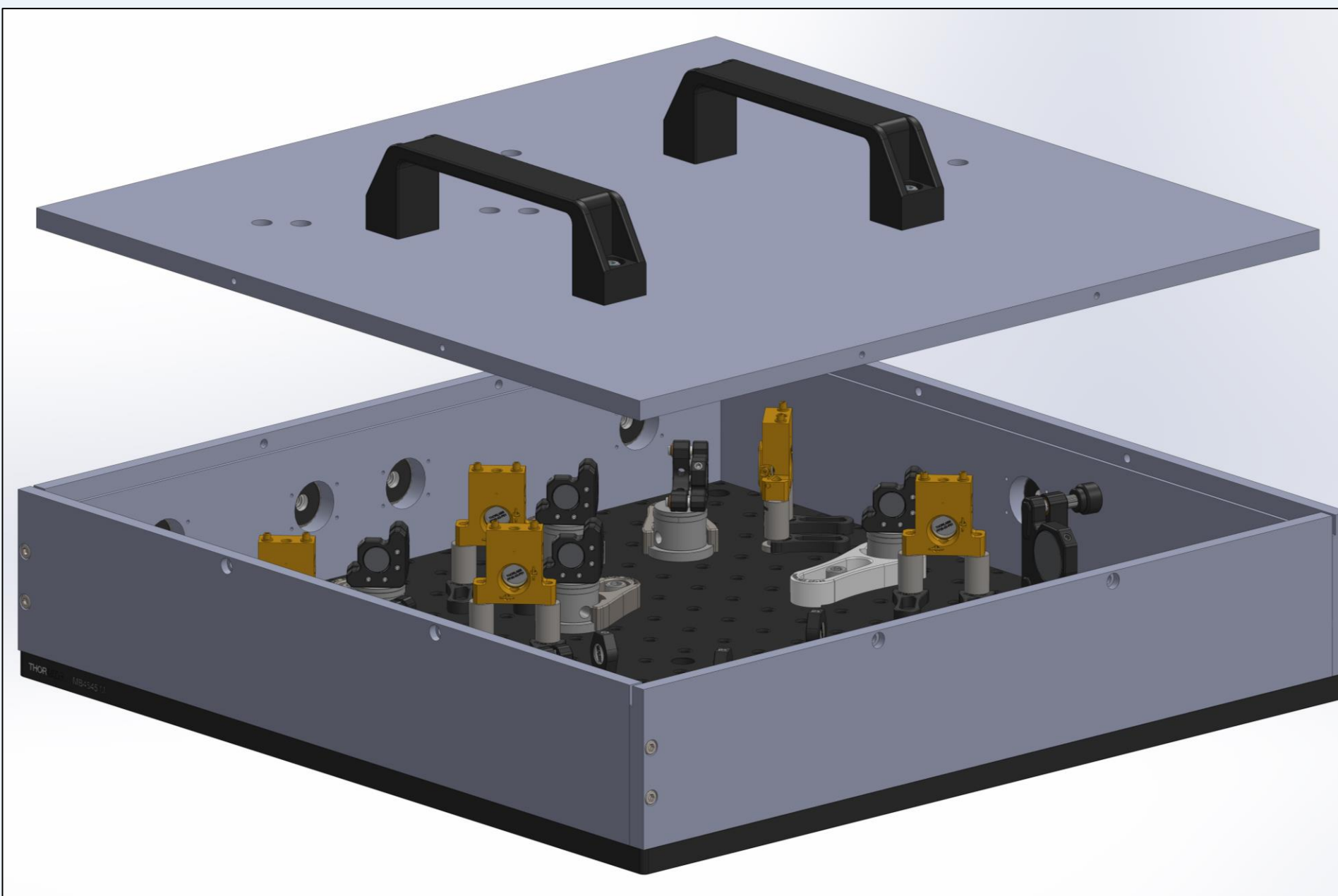
## ENCLOSURE DESIGN



SolidWorks is also used to design the enclosure for the device, with machined holes for the FiberPorts to be attached securely.

Some considerations in designing the enclosure include the stability and rigidity of the setup, and the ease of machining the parts required.

The pictures on the left illustrate the design of the enclosure. For ease of machining, the picture below shows the template design for the side walls of the enclosure.



## REFERENCES

- [1] Jones, D., 2000. Carrier-Envelope Phase Control of Femtosecond Mode-Locked Lasers and Direct Optical Frequency Synthesis. Science, 288(5466), pp.635-639.
- [2]"Visible Ruled Reflective Diffraction Gratings", Thorlabs.com. [Online]. Available: [https://www.thorlabs.com/images/tabImages/500\\_1200\\_Ruled\\_Grating\\_Efficiency\\_Graph\\_780.gif](https://www.thorlabs.com/images/tabImages/500_1200_Ruled_Grating_Efficiency_Graph_780.gif)
- [3]"Thorlabs - GR13-1205 Ruled Reflective Diffraction Grating, 1200/mm, 500 nm Blaze, 12.7 x 12.7 x 6 mm", Thorlabs.com, 2021. [Online]. Available: <https://www.thorlabs.com/thorproduct.cfm?partnumber=GR13-1205>
- [4]"Free Optical Simulation & Design Software | 3DOptix", 3DOptix. [Online]. Available: <https://3doptix.com/>