Design of a New Broadband Output Coupler for Optimal THz Laser Performance

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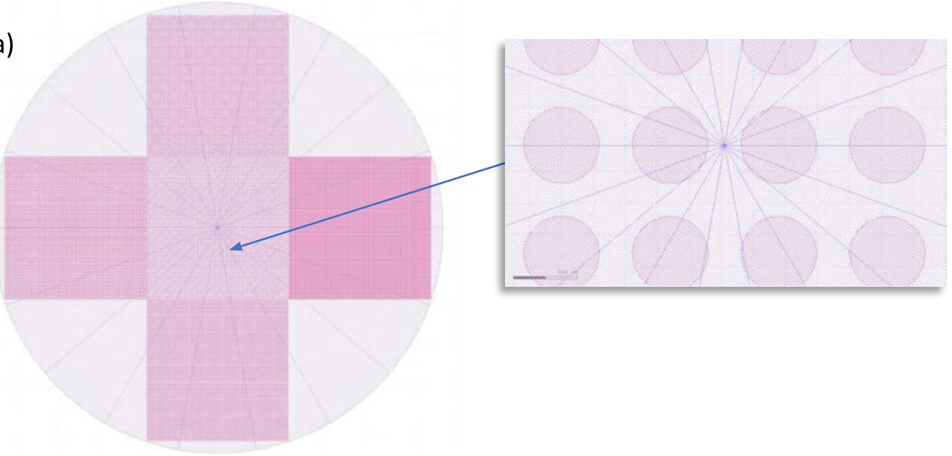
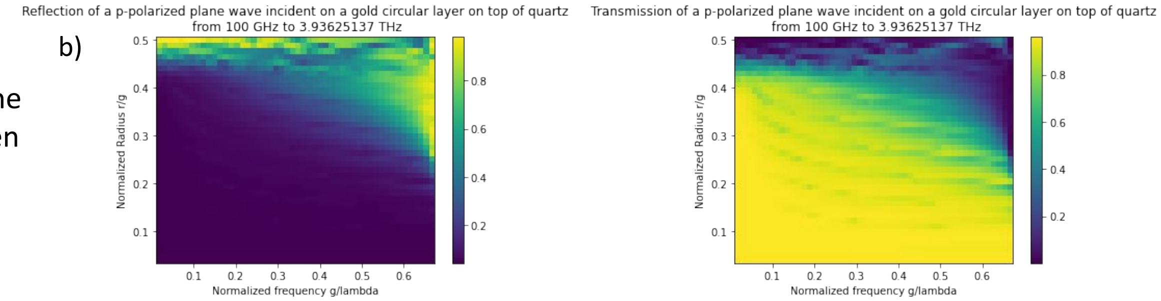
The terahertz gap of the electromagnetic spectrum from 0.1 to 20 THz is an intriguing area of research with many applications in physics, chemistry, biomedicine, material science, and communications. Terahertz frequencies are present in many systems from vibrations of biological molecules to resonance of electrons in semiconductors. Generating terahertz frequency radiation has been an important challenge in physics for several decades. Recently, the Capasso Group at Harvard proposed a quantum cascade laser (QCL)-pumped molecular laser (QPML) concept to generate tunable THz radiation that offers promising performance to fill the terahertz gap. The optical cavity of the QPML is the part of the laser containing the gas gain medium and two mirrors, one that is usually highly reflective and another, the output coupler, that is partially reflective. Originally, a pinhole coupler was used, but the efficiency was around 0.3 and the light was not especially uniform because of diffraction.

The purpose of my project was to design an output coupler with high reflection and low transmission because reflection inside the laser cavity amplifies the light by stimulated emission. The output coupler should also have high efficiency and low losses since unlike the previous CO_2 laser concepts, the losses of the output coupler for the QPML have to be taken into account since the lasing threshold cannot be too high for the QCL due to its available power in the 100 mW range while the OPFIR pumped by a CO_2 laser has around 100 W. Simulations with different designs, materials, sizes, and thicknesses were performed to get an optimal design that had high reflection and efficiency with low losses for a broad region of frequencies and the results indicated that the most promising design was an array of circles and that the optimal radius of the circles was 0.35 times the periodicity of the array. This design had a maximum efficiency of around 60%, making it an attractive alternative coupler for terahertz lasing applications.

a)





a) GDS diagram of the output coupler with 5 different arrays of circles. b) Reflection and Transmission colormaps for a p-polarized plane wave incident on a gold circular layer on top of quartz with high reflection and low transmission near g/lambda = 0.35

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Michael Bregar is majoring in physics and minoring in aerospace engineering at the California Institute of Technology (Caltech). I am very passionate about using mathematics and physics for tackling and solving important questions for humanity's betterment. Doing research through the Harvard SEAS REU program helped me to pursue this passion by running mathematical simulations to develop a new broadband output coupler to come closer to breaking the terahertz gap and contribute to the far infrared applications that can be used in medicine, physics, communications, and other fields to help us harness the laws of physics for practical uses. Working at Harvard also reaffirmed my desire to pursue a Ph.D. in physics and a career in research and academia.

Michael Bregar (left) with Dr. Chevalier (right) gathering data on the behavior of the quartz substrate for the new QPML output coupler design