DEPSCoR Year 1 Progress Report
Molecular gas-filled hollow optical fiber lasers in the near infrared

A. Introduction

The goal of this proposal is successfully demonstrate an optically pumped gas laser in hollow fiber (OPGFL). The overall goals for Year 1 were 1) to select a proper hollow fiber and molecular gas, and 2) to perform emission and absorption measurements. We have accomplished both of these tasks in Year 1 for lasing at ~1550 nm. In addition we have set up a proof-of-principle laser cavity our chosen molecular gas and have been the process of making the laser work. We are currently investigating schemes for lasing at 3 μm, an important wavelength for remote sensing applications.

B. Significant Results of Year 1

One goal for Year 1 was to identify molecular gases for the laser. We have identified the $\nu_1+\nu_3\rightarrow\nu_4$ transition in acetylene (C_2H_2) as one that may lase at 1600 nm. With the help of Wolfgang Rudolph at the University of New Mexico, we have also identified transitions in HCN that will also serve as an efficient laser at ~1550 nm. Furthermore, we have finished the design and construction of the OPGL cavity. Here we are investigating emission and absorption in C_2H_2. Two cavities for two pumping/lasing scenarios were designed using the transitions identified. The first cavity design was based on pumping at 1532 nm and lasing at ~1550 nm. The second cavity design was for pumping at 1532 nm and lasing at ~1650 nm.

For the first laser cavity configuration the separation of the pump and lasing wavelengths is challenging due to the tight proximity of the two wavelengths. If the polarizations of the pump and probe can be made orthogonal, then they can be readily separated. However, the intracavity beam must be nearly collimated when passing through the polarization optics, so after exiting the fiber, the beam passes through a vacuum window and a collimating lens before passing through the polarizing beam plate and high reflecting mirror. Unfortunately, the round-trip losses in this configuration were about 85%, most likely due to diffraction of the beam over the longer free-space section of the cavity. The significant drawback with this laser design is that the polarization multiplexing of the pump and lasing signal did not work due to coupling and collimation losses. While this may yet be improved, either by better coupling optics or with a dichroic mirror with reflection and transmission bands separated by ~10 nm, we chose to move on to a more promising system.

To avoid the problems using the polarization beam plate a second cavity design was constructed, pumped at 1532 nm for lasing at 1650 nm (on the $\nu_1+\nu_3\rightarrow\nu_4$ transition). In this case, dichroic mirrors can be used to separate pump and probe beams. The cavity is shown in the figure below. A 10 cm radius of curvature mirror was installed in the vacuum chamber and found to have a large enough region with the desired reflectivity near 1650 nm. Next, the pump was coupled into the fiber using a curved dichroic mirror that served as the high reflector (HR/DM) for the laser. The output coupler (OC) was another curved optic that reflected the pump and 99% of the laser light at 1650 nm. Both the high reflector and output coupler were fixed in bellows vacuum mounts so the optics could be tilted and translated.

At this point, the pulsed 1532 nm pump source and laser cavity have been designed and tested. Calculations by W. Rudolph indicate that the threshold should be near 1.1 W peak power in pulsed 100 ns mode, and that appears to be readily achievable with our pump source. However, alignment of the cavity for lasing at 1650 nm has proven challenging. Multiple wavelengths, at 1300 nm, 1550 nm, and 1600 nm have all been employed for alignment. It is difficult to ensure simultaneously that the HR/DM and OC are both aligned to retro-reflect the lasing beam back into the fiber. To ensure the HR/DM is retro-reflected, light at 1300 nm is used because it passes the OC (T~80% at 1300 nm), while to align the OC for retro-reflection, 1600 nm light is employed because the HR/DM has T~50% at 1600 nm. The alignment procedure is to couple 1300 nm light through the OC, into the fiber and to the HR where roughly 20% of the light is reflected back to the OC. The 1300 nm light that was reflected back through the OC was measured using a fiber circulator. This alignment step helped to position the OC with respect to the fiber in the vacuum chamber. Next, pump light at 1532 nm was coupled into the HR/DM, through

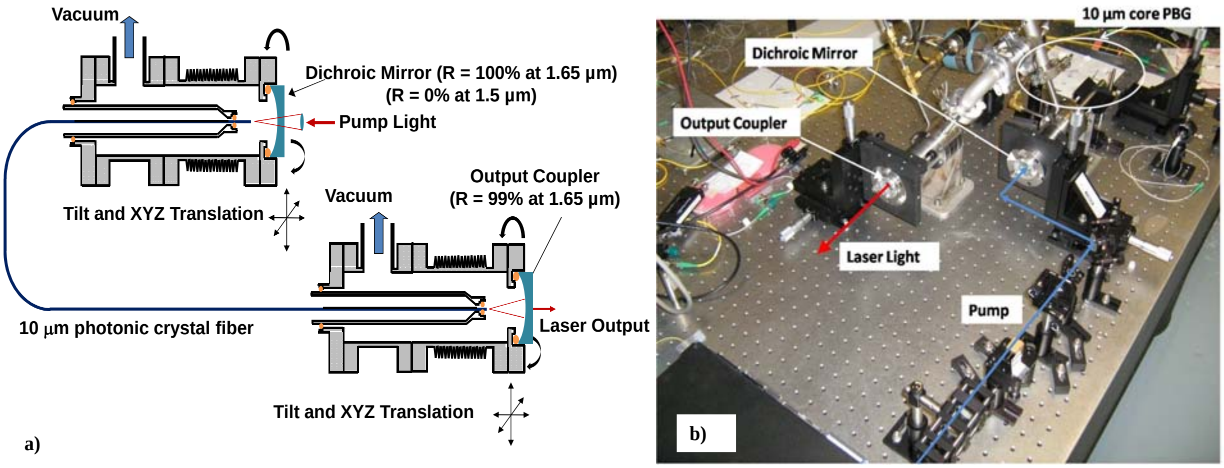

Fig. 1 a) The cavity for the scenario of pumping at 1532 nm and lasing at 1650 nm. b) Picture of the actual cavity.

the fiber, and to the OC where a portion was retro-reflected back to the HR/DM. The 1532 nm light that was reflected back through the HR/DM was measured using a rejection port of a free-space isolator for the pump. The cavity alignment is very sensitive to the position of the HR and OC. If the bare fiber extends too far from the vacuum seal, alignment will drift as pump power increases, because the hollow fiber heats and deflects with time. Short (~1 mm) bare fiber lengths mitigate these effects, and those of mechanical vibrations, as well. These technical difficulties have arisen in the testbed, but should be resolved in the all-fiber version of this laser.

We are currently investigating the power threshold for 3 μm lasing in C_2H_2 and HCN. We will need to determine the transmission of hollow-core fiber at 3 μm for it to serve as the laser cavity. To do these experiments we have upgraded our current spectrometer with a proper grating and detector for looking at emission at 3 μm. We have also purchased a 3 μm continuous wave He-Ne laser for measuring the transmission of hollow-core fiber. The power threshold experiments may need a high power pump source which we intend to purchase using the remaining equipment funds.

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