Generation of mid-IR wavelengths

DEBORAH ROBINSON, Robert Hartsock, and Kelly Gaffney
SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, CA

Introduction

The understanding of basic molecular dynamics can be obtained through pump/probe experiments. The pump is used to excite the molecule of interest at an absorption transition within the molecule to create a non-equilibrium state. The probe, which is usually a visible or infrared laser system, is then used to investigate changes, as a function of time, to the molecule. The probe acts as a camera taking pictures of changes occurring in the molecule. Pulse width requirements are very short in order to capture molecular processes like vibration or electronic relaxation usually hundredths of trillionths of a second. An understanding of basic molecular dynamics guides the way in choosing appropriate test materials for applications in solar energy, alternative fuels or computing processes. Here we present our work on generating mid-IR wavelengths to be used as a probe in these pump/probe experiments. As an example, one could use a visible pump to excite an electronic transition and then probe with the mid-IR to investigate changes on a nuclear level. It is to be noted that this was the first work done using this New Laser system in a New Lab in the Pulse Institute at SLAC.

Frequency Mixing equations

\[ \omega_\text{p} = \omega_\text{i} + \omega_\text{s} \]

<table>
<thead>
<tr>
<th>Frequency Difference</th>
<th>375 THz</th>
<th>158 THz</th>
<th>214 THz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength (nm)</td>
<td>800</td>
<td>1900</td>
<td>1400</td>
</tr>
<tr>
<td>Energy (eV)</td>
<td>1.55eV</td>
<td>.65eV</td>
<td>.89eV</td>
</tr>
</tbody>
</table>

Energy Levels

Mid-IR laser oscillator. The seed laser outputs over 435mW at 80MHz at 800nm. The regenerative amplifier is pumped by a frequency doubled YLF laser which outputs \(~ 7 W @ 5 kHz\) for \(~ 14.4 mJ/pulse\). In the regenerative amplifier, the beam is stretched temporally using a diffraction grating and then compressed temporally with a second diffraction grating and optics. The output from the regenerative amplifier is a 38 femtosecond \(~ 2.5 mJ/pulse beam of 800 nm @ 5 kHz\) supplying the pump to the Optical Parametric Amplifier (OPA).

In the OPA, a portion of the pump beam is focused into a sapphire crystal creating white light supercontinuum. This white light supercontinuum is mixed with the pump beam in a β-barium borate crystal (BBO) in two passes to yield the desired wavelengths in the near-IR. Here we have generated \(~ 400 mW of 1400 nm and 1900 nm near-IR wavelengths out of the OPA. These signal and idler output wavelengths from the OPA will then be frequency difference mixed in a AgGaS2 nonlinear crystal to yield the desired mid-IR wavelengths to test the mid-IR detector. Here we have calculated an output mid-IR wavelength of 5.3μm from the AgGaS2 crystal for frequency difference mixing of the 1400nm and 1900nm wavelengths.

Conclusion and Discussion

1400 nm and 1900 nm near-IR wavelengths have been generated using an Optical Parametric Amplifier Laser System. These wavelengths can be frequency difference mixed to yield mid-IR wavelengths of 5.3μm. Wavelengths of 3μm-7μm are desired for the testing of the mid-IR detector. By changing the phase matching angle of the BBO in the OPA, different output wavelengths from the OPA can be obtained to frequency difference mix in a second non-linear crystal to yield the desired wavelength range for the testing of the mid-IR detector. The STAR research presented here is part of an ongoing research effort in the Pulse institute at SLAC National Laboratory.