

Optical Harmonic Generation

1 CAUTION!

The pulsed laser energies used in this lab constitute a safety hazard of which you need to be aware. There are two types of goggles for use. The green ones block out the infrared but not the green (second harmonic) light. The orange ones block out both. Always wear goggles when the laser is operating. Always keep the door closed when the laser is operating. Make sure people knock before entering. Turn off the laser when not in use. Do not look even at stray beams.

Always use a beam block to stop the beams. The laser can burn holes in just about everything (including the cinderblock walls).

Again:

ALWAYS WEAR LASER SAFETY GOGGLES IN THE EXPERIMENT

In this lab you will be generating harmonics of a pulsed Nd:YAG laser. Procedurally this is a relatively simple lab. Harmonic generation would be a trivial exercise would it not be for the problem of *phase matching*. Understanding phase-matching issues is what makes the lab difficult. In fact phase matching is a very tedious but not difficult subject to master. If you do not already have a background in it, you will find it useful and probably necessary to read the attached material.

Please do not begin your experiments until you have read through both experimental portions (the next two sections).

2 Experiments I

This first portion of this experiment is very much cookbook. Read through the Continuum Laser manual. Setup the laser for fundamental (1.06 μm), second harmonic (533 nm), third harmonic (355 nm) and fourth harmonic (266 nm) generation as it indicates in the manual. You cannot see the 1.06 μm radiation, so use the infrared card *with the laser in low energy mode and with the attenuator (on top of the laser) nearly full in place*. Otherwise you will put a hole in the viewer card.

You will need to remove the cover of the laser to perform each setup. Be careful when removing and replacing the laser optics. In particular, note that the head of one of the two screws holding down each mirror mount is too big to be removed. Therefore, remove the other screw first, and unscrew the second one while lifting up the mount. Be careful not to touch any optical surfaces.

Use the laser energy meter (not a photodiode) to measure the output power of the various harmonics when the laser is in its high-energy mode. You can set the attenuator for maximum output. Return to low energy mode. For the 355 nm and 266 nm, place a few things in the path of the laser (like a business card if you have one) and note the fluorescence.

3 Experiments II

This time you will use an external KTP crystal to double the 1.06 μm radiation to produce 532 nm light. Your goal is to measure the second harmonic generation characteristics as a function of input polarization, input power, and angles of incidence.

Be very careful with the KTP crystal –it is expensive!

The major pieces of equipment for this portion of the lab are the KTP crystal, a high-energy half waveplate for 1.06 μm and a dichroic beamsplitter. The latter are designed to be used at 45° incidence. It reflects the 1.06 radiation, and transmits the 532 radiation. It is very handy when making relative power measurements.

The attached information on KTP gives the relevant parameters needed to determine the optimum phase-matching condition. In order to know what to expect you will need to have worked through the prelab problems. Once you have done so, you can carry out the following procedure.

1.1 PROCEDURE:

1. Set up the Nd:YAG laser to output its 1.06 μm light.
2. Set the laser on low energy mode.
3. The KTP crystal is mounted on a “prism table” that allows you to vary the orientation of the crystal. You can determine the angle of incidence using the light reflected from the front surface of the crystal.
4. Arrange the light to go through the KTP crystal. At normal incidence you should see quite a bit of green light generated by the crystal.
5. Determine the input and output polarization. (Put the laser beam on low power to do this or you will (again) burn a hole in the polarizer).
6. Now arrange an optical system so you can vary the input polarization (with the half-wave plate) and the angle of incidence on the crystal. (There should be some rotation stages around the room). You will have to do the two rotation planes separately, first in one plane, then rotate the crystal by 90° and make measurements in the other plane.
7. Use the dichroic beamsplitter to separate the infrared and green beams.
8. As a function of input angle, input polarization and input power, measure the output polarization and intensity of the second-harmonic.
9. What are the salient features of your results?
10. Use a plastic ruler to estimate the interaction length of your crystal.
11. Plot the output power versus input power for the optimum angle of incidence. Is it in good agreement with theory? How good (or bad)?

12. Plot the output power versus input angle for fixed input intensity. The intensity versus angle plot should be against the internal angle, so use Snell's law. Are your results in good agreement with theory? How good (or bad)?

4 Prelab Exercises

You will be using KTP for your harmonic generation experiments. You will find the relevant nonlinear optical coefficients for KTP attached to this write-up. From this material you should learn that KTP is birefringent and is typically used with Type II phase-matching. That means, for example, that the harmonic experiences the phenomenon called beam-walkoff. See the Hopf and Stegeman material. Note that this material covers the major topics you will need to answer the prelab questions and know what you are doing in the lab! In particular it covers second-harmonic generation, Type I and Type II phase-matching (you will need the latter), beam walkoff, critical angle, effective nonlinear coefficients for second-harmonic generation and index contraction.

The crystal is already cut properly to achieve phase-matching for a fundamental wave at normal incidence and propagating along the long direction. The crystal you will be using is about 3 mm x 3 mm x 8 mm but for the following you can simply suppose it provides about 5 mm path length.

1. What is (are) the optimum input beam direction and polarization for second harmonic generation (fundamental wavelength = 1.06mm)? (Calculate them, and you can check your answer against the included data sheets –you typically find some difference in the values quoted by manufactures.)
2. Calculate the critical angle.
3. What is the walk-off angle? Calculate it for KTP used at 1.06 for second-harmonic generation.
4. For a fixed input power, plot the output power as a function of input beam direction. Measure the angle from the optimum direction. Does the output depend on two angle variables or one? If two, either make a 3D plot that covers the two rotation planes, or do two plots in orthogonal planes.
5. For a fixed input power and for an input beam in the optimum direction, plot the output power as a function of input polarization.
6. Assuming the laser gives a square pulse as characterized above, what efficiency of second-harmonic conversion do you expect (output power in the green over input power in the infrared)?
7. The pulse width of the laser is not a function of its output intensity. Plot the expected second-harmonic intensity as a function of the input intensity.