PSE605A (Photonics Lab Techniques)

Lab Report: Experiment 8

Nd:YAG Laser

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Contents

List of Tables

Nd:YAG laser and 2nd harmonic generation

1 Objectives

- To align the Nd:YAG laser, observe the lasing wavelength (1064 nm) and hence to find the threshold pump power.
- To produce second harmonics in the existing set up by using the given KTP Crystal, observe frequency-doubled radiation (532 nm) and find the power conversion efficiency.

2 Equipments

Diode laser (808nm), Collimator, Focussing lens, Nd:YAG rod, KTP crystal, Mirror, Mounts, Filter plate, Spectrum analyser, Photodetector, Multi-meter and connecting wires.

3 Theory

Nd:YAG (neodymium-doped yttrium aluminium garnet; Nd:Y3Al5O12) is a crystal that is used as a lasing medium for solid-state lasers. The dopant, triply ionized neodymium, Nd (III), typically replaces a small fraction (1(YAG), since the two ions are of similar size. It is the neodymium ion which provides the lasing activity in the crystal, in the same fashion as red chromium ion in ruby lasers. A neodymium YAG laser is pumped by a matched laser diode of high efficiency, resulting in a compact, high-efficiency and long-lifetime laser assembly. The wavelength of diode emission therefore matches an absorption band of the Nd-YAG crystal very well. It is possible to achieve efficiencies of 50-80range, but can be converted to the visible spectrum by an internal frequency doubler. A doubling crystal, which may be a KTP crystal, is placed at an optimum location in the laser cavity. Nd:YAG laser generates laser light commonly in the near-infrared region of the spectrum at 1064 nanometers (nm). It also emits laser light at several different wavelengths including 1440 nm, 1320 nm, 1120 nm, and 940 nm.
Typical neodymium doping concentrations are of the order of 1be advantageous e.g. because they reduce the pump absorption length, but too high concentrations lead to quenching of the upper-state lifetime e.g. via up-conversion processes. Also, the density of dissipated power can become too high in high-power laser

4 Procedure

The Nd:YAG laser unit consists of the following components:
Module A Diode laser
Module B Collimator
Module C Focusing unit
Module D Laser mirror adjustment holder with Nd YAG rod
Module E Laser mirror adjustment holder
Module F Filter plate holder
Module G Photo detector
Module H Controller unit LDC01
The module A is positioned on the optical rail and clamped. The current control on the front panel of the control unit should be fully turned to the left. It can be seen that the diode laser beam is very divergent. The collimator is then placed in front of the diode laser module. The collimator has a focal length of 6 mm. The focus is located about 1-2 mm in front of the entry surface of the collimator. The light from the laser diode is almost parallel for a certain collimator position. Consequently the diode laser is Blocked Off and the focusing unit positioned on the rail. This unit contains a biconvex lens with a focal length of 60 mm. It is later used for focusing the diode laser beam into the YAG rod. It is practical to set up the focusing module at a distance of about 80-100mm from the collimator. The focus of the diode laser beam is produced at a distance of about 60mm from the main plane of the biconvex lens. The YAG rod should be positioned at this point, so that the focus is located within the rod. The position of the focus can be found on a piece of white paper.

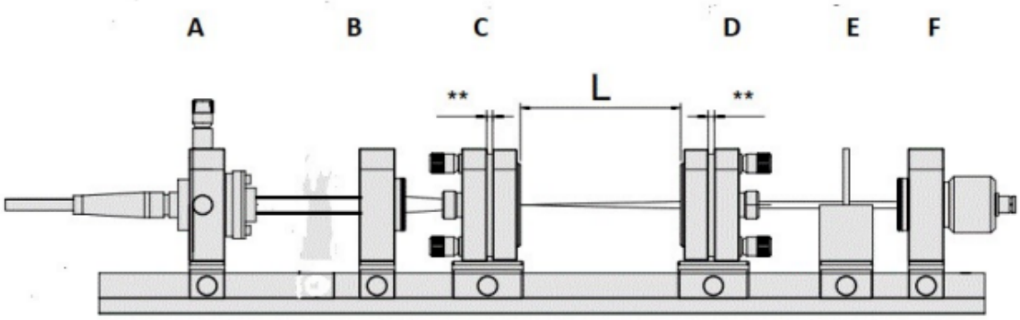

Figure 1: experimental set up

4.1 Procedure for lasing

1. The equipment is first configured as shown in Figure 2, moving the photo detector closer to Module C, the focusing unit, so that Module D, the YAG rod, can also be inserted into the space left by the focusing unit and photo detector.
2. Now place the YAG rod between the photo detector and the focusing unit(Fig 3) so that the focusing unit's focus fully illuminates the YAG rod.
3. Place Module E, the output coupler mirror, in place.
4. Place the RG 1000 filter (808 nm blocking 1064 nm pass filter) in place.
5. Take out the photo detector at this point, leaving a fiber optic cable installed, and launch the "SpectraSuite" program.
6. Gradually increase the LD current as you watch the monitor's spectrum to determine the lasing wavelength.
7. Reinstall the photo detector, adjust the LD current (but not more than 2 A), and record the output voltage that results.
8. Determine the pump power that corresponds to various LD current values using the supplied data (V-I values for the laser diode), and then plot the Nd: YAG laser's output power as a function of the pump power. Determine the pump power threshold.

4.2 Procedure of Second Harmonic Generation

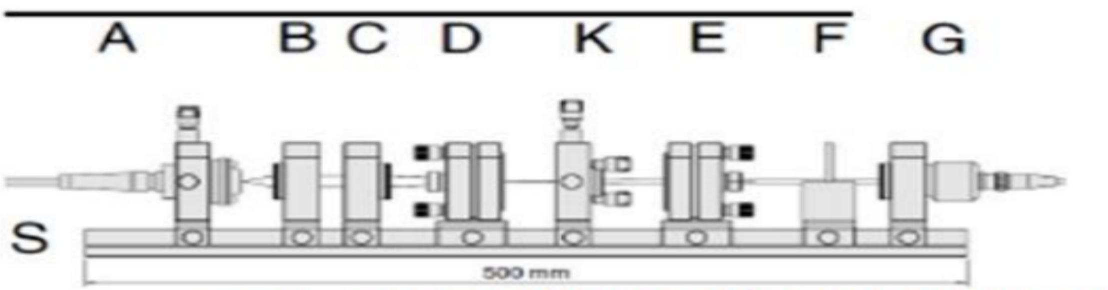

Figure 2: set up for SHG

The second harmonic at 532 nm of the fundamental wave (1064 nm) is generated by means of a KTP crystal (Module K) 1. Place the KTP crystal at a certain position in between Module D and the Module E.
2. Now switch on the laser diode. We can see a green colored beam. Then put a filter to block 808nm and 1064 nm. If the beam is not observed then try changing the position of the KTP crystal and it must usually give a beam when placed at certain position.
3. Now remove the photodetector and observe 532 nm using fiber optic cable and 'SpectraSuite'.
4. Place the photodetector back and note the output voltage on varying the LD current.
5. Plot the output power of the frequency doubled radiation as a function of pump power. And find threshold power.
6. Measure the 1064nm power to the KTP corresponding to one value of LD current and also measure the 532nm power corresponding to same LD current. Find the power conversion ratio.

5 Observation tables

5.1 Pump output

LD current (A)	recorded output voltage (V)	Actual output voltage (V)	Actual output current (mA)	recorded output power (mW)
0.6	0.397	0.661666667	0.661666667	0.708928571
0.61	0.397	0.661666667	0.661666667	0.708928571
0.62	0.4	0.666666667	0.666666667	0.714285714
0.63	0.403	0.671666667	0.671666667	0.719642857
0.64	0.404	0.673333333	0.673333333	0.721428571
0.65	0.407	0.678333333	0.678333333	0.726785714
0.66	0.409	0.681666667	0.681666667	0.730357143
0.67	0.412	0.686666667	0.686666667	0.735714286
0.68	0.414	0.69	0.69	0.739285714
0.69	0.419	0.698333333	0.698333333	0.748214286
0.7	0.419	0.698333333	0.698333333	0.748214286
0.71	0.419	0.698333333	0.698333333	0.748214286
0.72	0.421	0.701666667	0.701666667	0.751785714
0.73	0.425	0.708333333	0.708333333	0.758928571
0.74	0.426	0.71	0.71	0.760714286
0.75	0.43	0.716666667	0.716666667	0.767857143
0.76	0.432	0.72	0.72	0.771428571
0.77	0.436	0.726666667	0.726666667	0.778571429
0.78	0.438	0.73	0.73	0.782142857
0.79	0.443	0.738333333	0.738333333	0.791071429
0.8	0.447	0.745	0.745	0.798214286
0.81	0.45	0.75	0.75	0.803571429
0.82	0.454	0.756666667	0.756666667	0.810714286
0.83	0.463	0.771666667	0.771666667	0.826785714
0.84	0.473	0.788333333	0.788333333	0.844642857
0.85	0.473	0.788333333	0.788333333	0.844642857
0.86	0.487	0.811666667	0.811666667	0.869642857
0.87	0.496	0.826666667	0.826666667	0.885714286
0.88	0.496	0.826666667	0.826666667	0.885714286
0.89	0.51	0.85	0.85	0.910714286
0.9	0.51	0.85	0.85	0.910714286
0.91	0.512	0.853333333	0.853333333	0.914285714
0.92	0.515	0.858333333	0.858333333	0.919642857
0.93	0.523	0.871666667	0.871666667	0.933928571
0.94	0.525	0.875	0.875	0.9375
0.95	0.528	0.88	0.88	0.942857143
0.96	0.533	0.888333333	0.888333333	0.951785714
0.97	0.538	0.896666667	0.896666667	0.960714286
0.98	0.538	0.896666667	0.896666667	0.960714286
0.99	0.544	0.906666667	0.906666667	0.971428571
1	0.544	0.906666667	0.906666667	0.971428571

Table 1: Pump output

5.2 Nd: YAG (1064 nm)

LD current (A)	recorded output voltage (V)	Actual output voltage (V)	Actual output current (mA)	recorded output power (mW)
0.6	0.247	0.411666667	0.411666667	0.52
0.61	0.247	0.411666667	0.411666667	0.52
0.62	0.249	0.415	0.415	0.524210526
0.63	0.25	0.416666667	0.416666667	0.526315789
0.64	0.253	0.421666667	0.421666667	0.532631579
0.65	0.253	0.421666667	0.421666667	0.532631579
0.66	0.257	0.428333333	0.428333333	0.541052632
0.67	0.257	0.428333333	0.428333333	0.541052632
0.68	0.259	0.431666667	0.431666667	0.545263158
0.69	0.262	0.436666667	0.436666667	0.551578947
0.7	0.262	0.436666667	0.436666667	0.551578947
0.71	0.264	0.44	0.44	0.555789474
0.72	0.264	0.44	0.44	0.555789474
0.73	0.268	0.446666667	0.446666667	0.564210526
0.74	0.269	0.448333333	0.448333333	0.566315789
0.75	0.272	0.453333333	0.453333333	0.572631579
0.76	0.277	0.461666667	0.461666667	0.583157895
0.77	0.277	0.461666667	0.461666667	0.583157895
0.78	0.29	0.483333333	0.483333333	0.610526316
0.79	0.309	0.515	0.515	0.650526316
0.8	0.309	0.515	0.515	0.650526316
0.81	0.324	0.54	0.54	0.682105263
0.82	0.324	0.54	0.54	0.682105263
0.83	0.332	0.553333333	0.553333333	0.698947368
0.84	0.336	0.56	0.56	0.707368421
0.85	0.343	0.571666667	0.571666667	0.722105263
0.86	0.357	0.595	0.595	0.751578947
0.87	0.368	0.613333333	0.613333333	0.774736842
0.88	0.37	0.616666667	0.616666667	0.778947368
0.89	0.375	0.625	0.625	0.789473684
0.9	0.378	0.63	0.63	0.795789474
0.91	0.385	0.641666667	0.641666667	0.810526316
0.92	0.385	0.641666667	0.641666667	0.810526316
0.93	0.395	0.658333333	0.658333333	0.831578947
0.94	0.395	0.658333333	0.658333333	0.831578947
0.95	0.404	0.673333333	0.673333333	0.850526316
0.96	0.408	0.68	0.68	0.858947368
0.97	0.411	0.685	0.685	0.865263158
0.98	0.414	0.69	0.69	0.871578947
0.99	0.421	0.701666667	0.701666667	0.886315789
1	0.425	0.708333333	0.708333333	0.894736842

Table 2: Nd: YAG (1064 nm)

5.3 Nd: YAG double (532 nm)

LD current (A)	recorded output voltage (V)	Actual output voltage (V)	Actual output current (mA)	recorded output power (mW)
0.7	0.013	0.021666667	0.021666667	0.04
0.71	0.014	0.023333333	0.023333333	0.043076923
0.72	0.014	0.023333333	0.023333333	0.043076923
0.73	0.014	0.023333333	0.023333333	0.043076923
0.74	0.014	0.023333333	0.023333333	0.043076923
0.75	0.014	0.023333333	0.023333333	0.043076923
0.76	0.015	0.025	0.025	0.046153846
0.77	0.015	0.025	0.025	0.046153846
0.78	0.011	0.018333333	0.018333333	0.033846154
0.79	0.021	0.035	0.035	0.064615385
0.8	0.024	0.04	0.04	0.073846154
0.81	0.035	0.058333333	0.058333333	0.107692308
0.82	0.059	0.098333333	0.098333333	0.181538462
0.83	0.106	0.176666667	0.176666667	0.326153846
0.84	0.132	0.22	0.22	0.406153846
0.85	0.144	0.24	0.24	0.443076923
0.86	0.16	0.266666667	0.266666667	0.492307692
0.87	0.167	0.278333333	0.278333333	0.513846154
0.88	0.174	0.29	0.29	0.535384615
0.89	0.182	0.303333333	0.303333333	0.56
0.9	0.187	0.311666667	0.311666667	0.575384615
0.91	0.186	0.31	0.31	0.572307692
0.92	0.192	0.32	0.32	0.590769231
0.93	0.194	0.323333333	0.323333333	0.596923077
0.94	0.2	0.333333333	0.333333333	0.615384615
0.95	0.2	0.333333333	0.333333333	0.615384615
0.96	0.204	0.34	0.34	0.627692308
0.97	0.208	0.346666667	0.346666667	0.64
0.98	0.209	0.348333333	0.348333333	0.643076923
0.99	0.211	0.351666667	0.351666667	0.649230769
1	0.214	0.356666667	0.356666667	0.658461538

Table 3: Nd: YAG double (532 nm)

6 Results & Plots

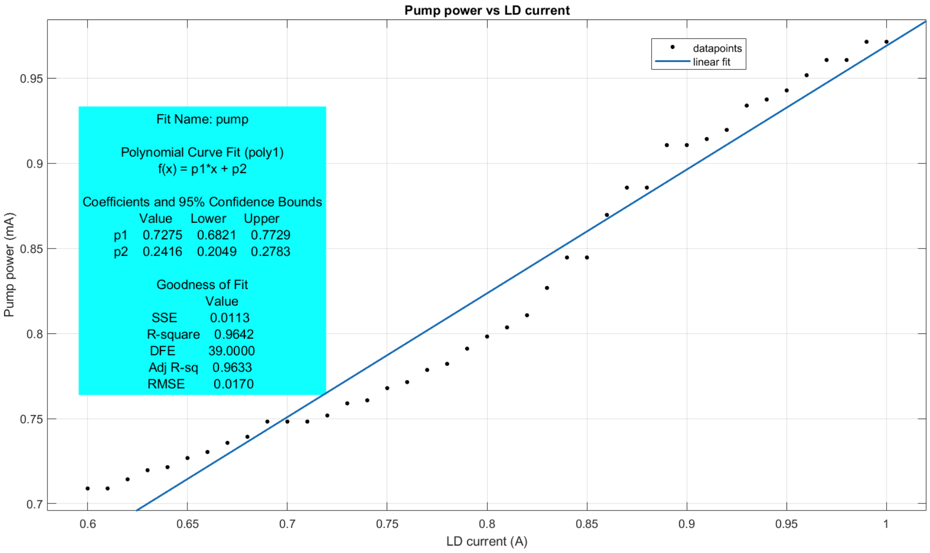

Figure 3: Pump output

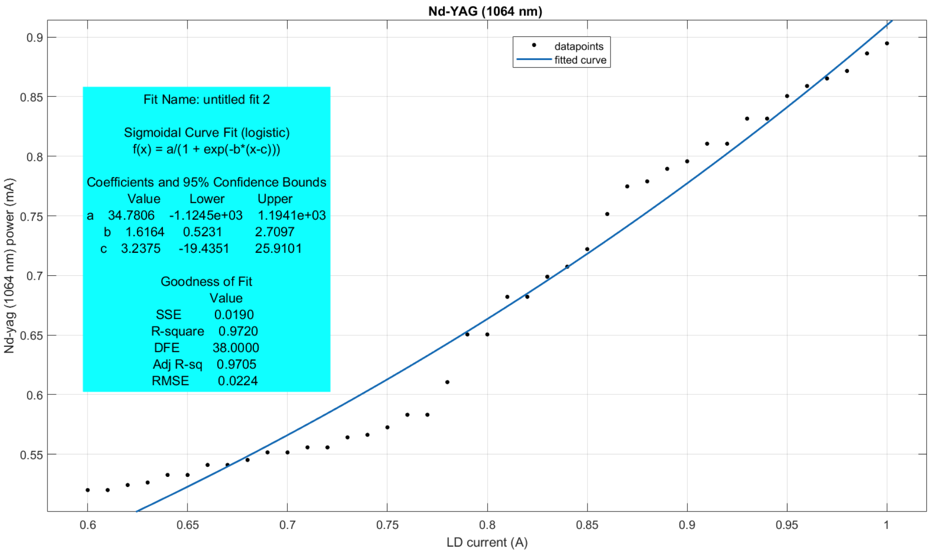

Figure 4: Nd:YAG (1064 nm) output

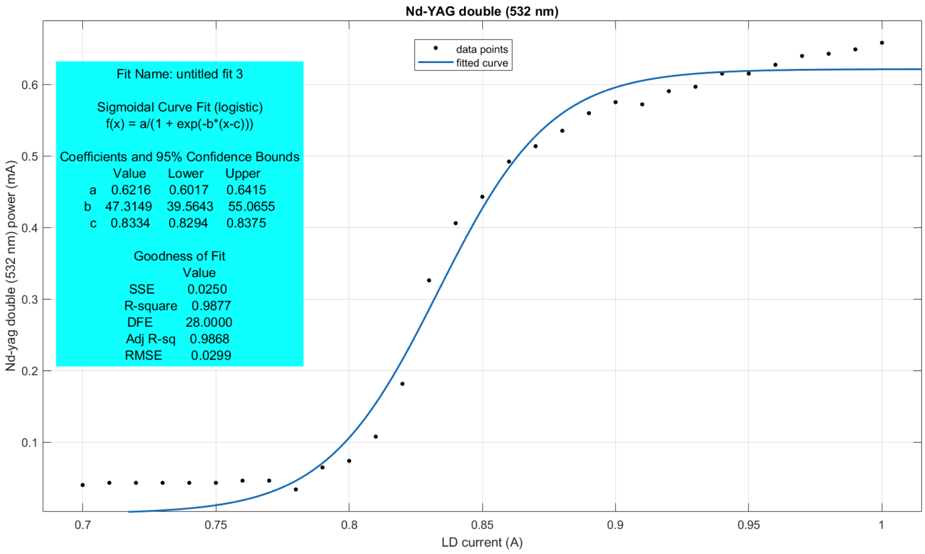

Figure 5: Nd:YAG (532 nm) output

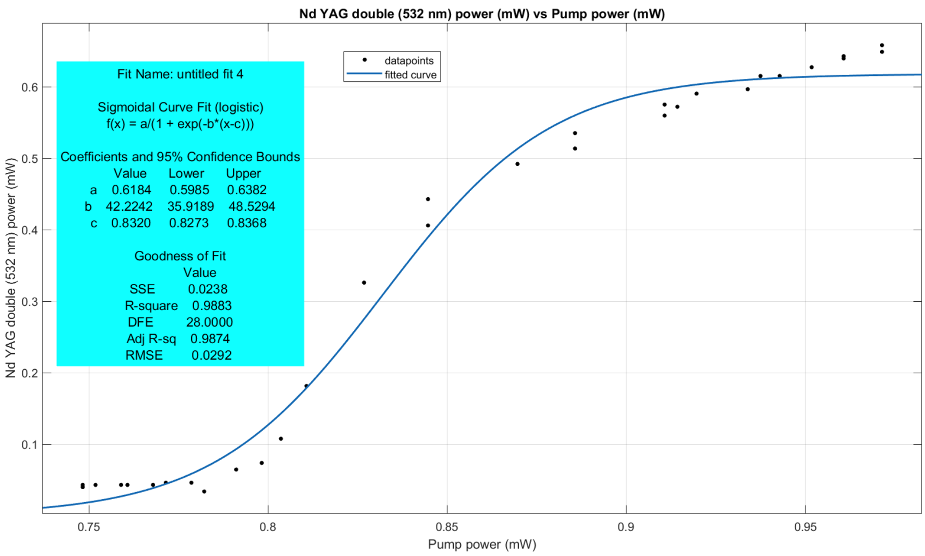

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Figure 6: Nd:YAG (532 nm) output vs pump output

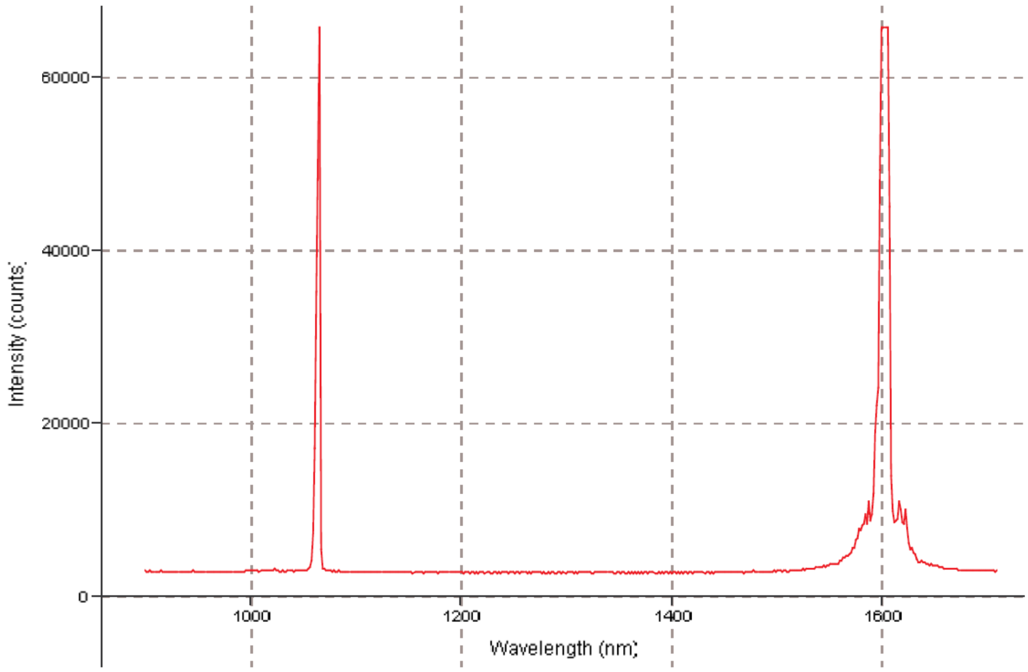
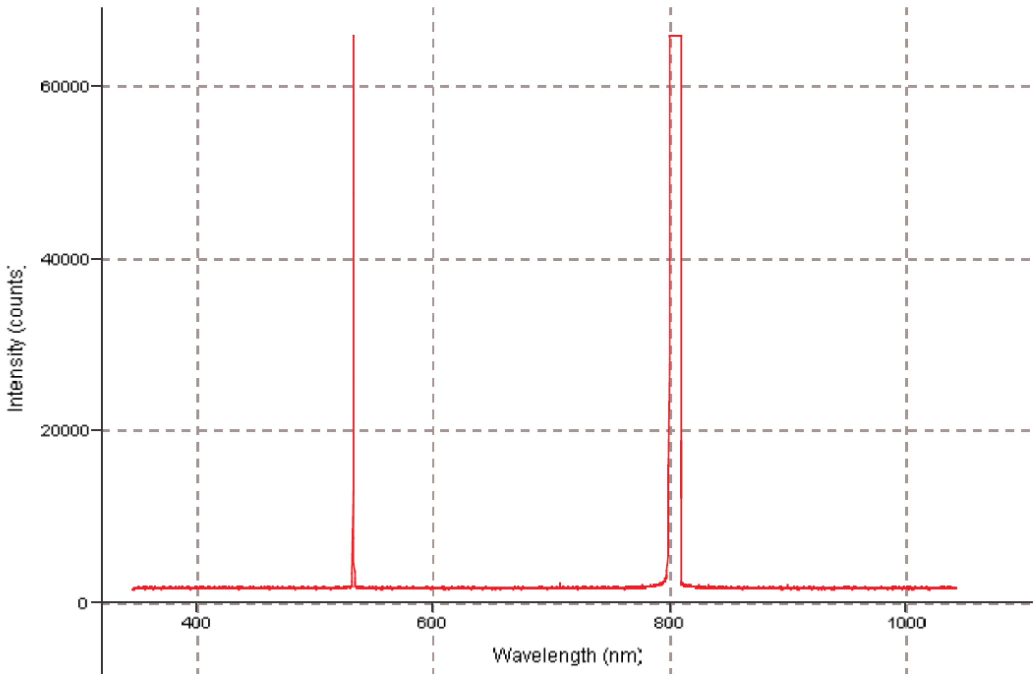


Figure 7: Nd:YAG (1064 nm) intensity distribution



[width=15 cm]

Figure 8: Nd: YAG double (532 nm) intensity distribution

7 Appendix

Wavelength (nm)	Detector Responsivity (A/W)
808	0.56
1064	0.475
532	0.325

Table 4: Responsivity at different wavelengths

- Resistance of the biasing circuit = 1KΩ
- Least count of Multimeter = 0.01mV
- Least count of DC power supply = 0.01 A
- Transmittance of RG1000 = 0.6 (Approx)
- Transmittance of Green Filter = 0.6 (Approx)

8 Discussions & Conclusions

- In this experiment, alignment is very important. For generating a laser, the distance between two curve mirrors has to precised. Otherwise, laser output is not possible.
- As a pump source, the diode laser is used with a wavelength of 808 nm. But in the intensity spectrum, there is a peak at 1600 nm. It is still unknown why it appears in the output.
- During generating the second harmonic generation (SHG), The output is very low. The output voltage detected in the detector is in the mili volt order.
- In second harmonic generation, the position of the KTP crystal is too sensitive. It has to be fixed at the precise position. Otherwise, the Nd: YAG double (532 nm) can not be generated.
- The RG1000 filter is used to reduce the intensity of the output. Otherwise, the detector might be damaged.
- The room has to be completely dark. Otherwise the noise will affect the actual output.

9 References

- “Principles of Lasers” by Svelto and Orazio, Springer publication, 4th edition (1998)
- ”Laser fundamentals” by William T. Silfvast, Cambridge University press, 2nd edition (2004) ”Laser fundamentals” by William T. Silfvast, Cambridge University press, 2nd edition (2004)