EO Experiment 1

Laser Experiment

Report

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Contents

1 Completing the Laser

The laser in the experiment is an incomplete IR (infrared) laser. It has a pump source, a gain medium, but one mirror of the optical cavity is not present. Complete the optical cavity by adding a mirror to the setup, and adjust the mirror until the laser starts lasing.

- (1). Turn on the power source, set the output mode to Current (I), the Complience Voltage to $4V$, and turn the Output Current to max ($0.95A$). This will turn on the pump source (which is also a laser in this case).
- (2). Turn on the alignment laser, which points in the center of the optical cavity.
- (3). Place the 95% R (reflectance) mirror on the 1^{st} mount, closest to the pump laser, and adjust the mirror until the IR laser starts lasing. (IR light can be checked using the IR card.)

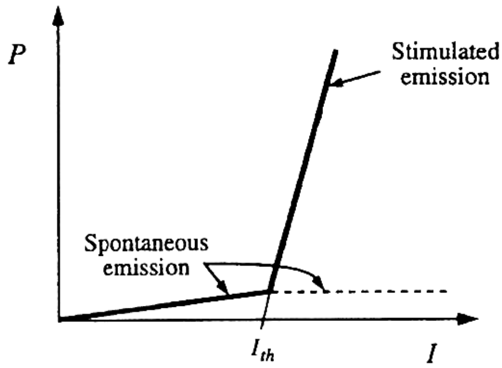
Notice how sensitive the alignment of the laser is, and what happens to the alignment laser after the IR laser is on.

Observations

校準的靈敏度非常高，稍微偏離就是未完成校準。

校準完畢後，小雷射的光點會消失。因為小雷射的增益因子被大雷射破壞了

2 Threshold Current

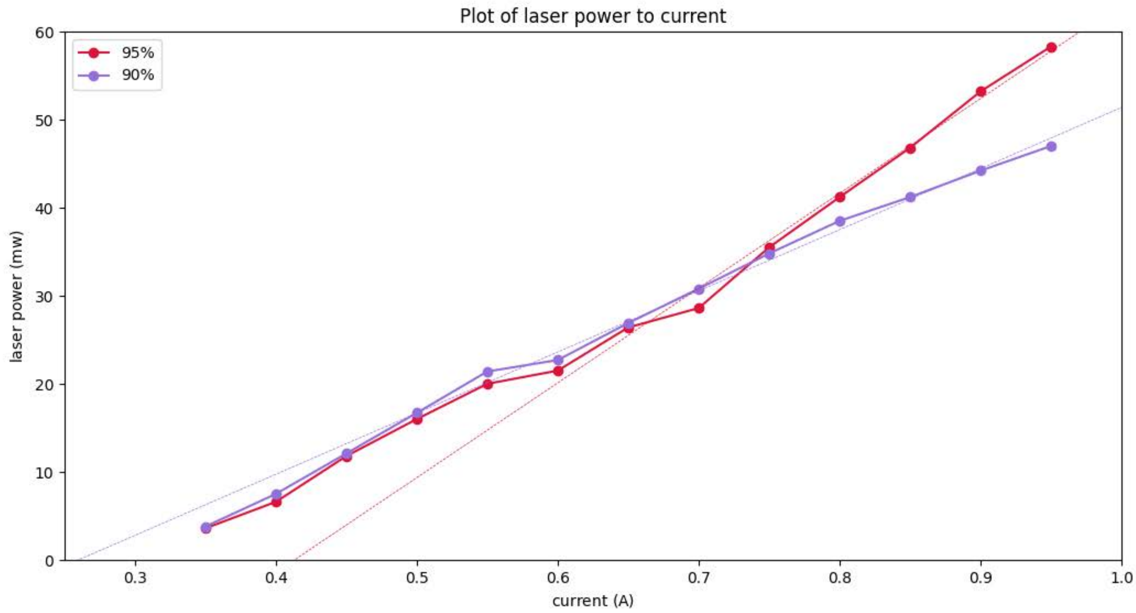


The threshold current is the intercept, of the linear stimulated emission part of the I-P curve, on the I axis.

- (1). Make sure that the alignment laser has been turned off. Remove the alignment laser from the mount using the hexagonal wrench,
- (2). Put an aperture on the 3^{rd} mount to block off the unused light from the pump laser.
- (3). Place the power meter in the path of the IR laser. Before measuring, block the detector and zero the meter.
- (4). Adjust the pump current and record the IR laser power.
- (5). After measuring, turn the pump current off and mount the alignment laser, select a mirror with a different R, and re-do the experiment.

95% R		90% R	
Current (A)	Power	Current (A)	Power
0.95	58.3	0.95	47.0
0.90	53.2	0.90	44.2
0.85	46.8	0.85	41.2
0.80	41.2	0.80	38.5
0.75	35.5	0.75	34.8
0.70	28.6	0.70	30.8
0.65	26.4	0.65	26.9
0.60	21.5	0.60	22.7
0.55	20.0	0.55	21.4
0.50	16.0	0.50	16.7
0.45	11.8	0.45	12.1
0.40	6.6	0.40	7.4
0.35	3.6	0.35	3.8

Plot the two I-P curves.



Calculate the threshold current I_{th} of the IR laser using two different cavity R.

We choose data points with current greater than $0.6(\mathrm{A})$, and find the linear regression of the chosen data points.

For 95%, the linear regression is $P = 107.6I - 44.449(\mathrm{mw})$, therefore $I_{th} = 0.413(\mathrm{A})$

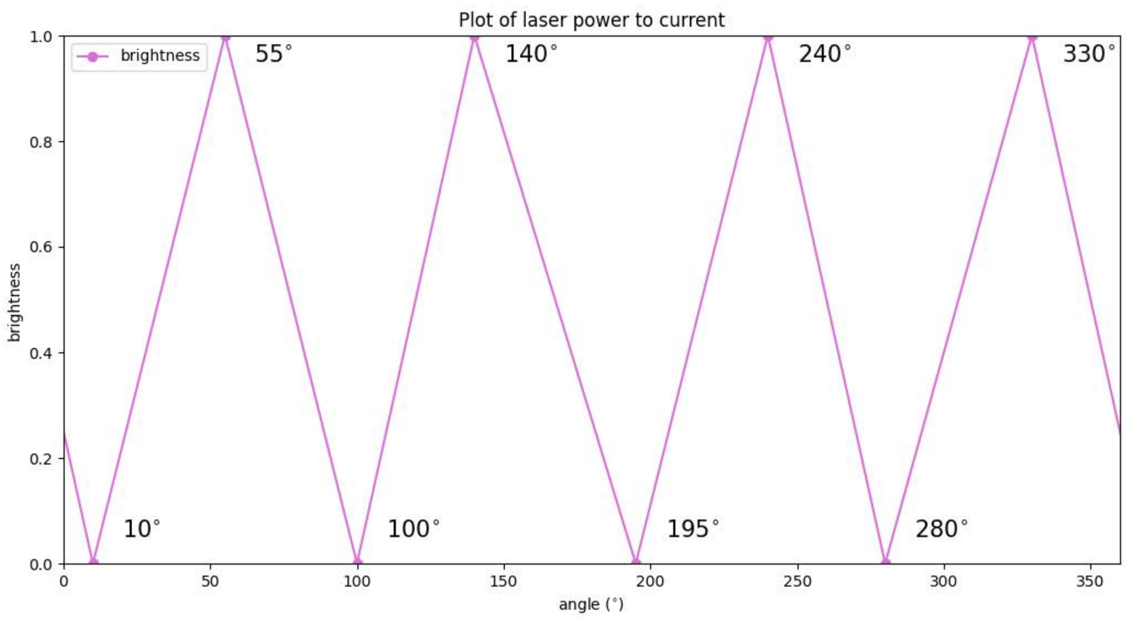
For 90%, the linear regression is $P = 69.405I - 18.026(\mathrm{mw})$, therefore $I_{th} = 0.260(\mathrm{A})$

3 Second Harmonic Generation

The IR laser have wavelength λ_{IR} of 1064 nm. In order to produce a green laser light, a non-linear SHG crystal is often used to double the frequency of the incident light, converting IR light into green light, in this case at λ_{Green} of 532 nm.

- (1). Switch the cavity mirror back to 95% R.
- (2). Set the pump current to max ($0.95A$).
- (3). Mount the SHG crystal on the 2^{nd} mount.
- (4). Rotate the crystal about the optical axis, observe the output and draw a rough graph of the Angle-Intensity curve.

Draw a rough graph of the Angle-Intensity curve of the SHG output.

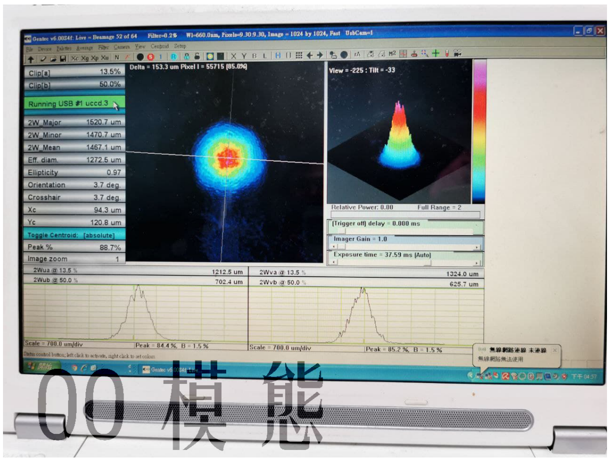


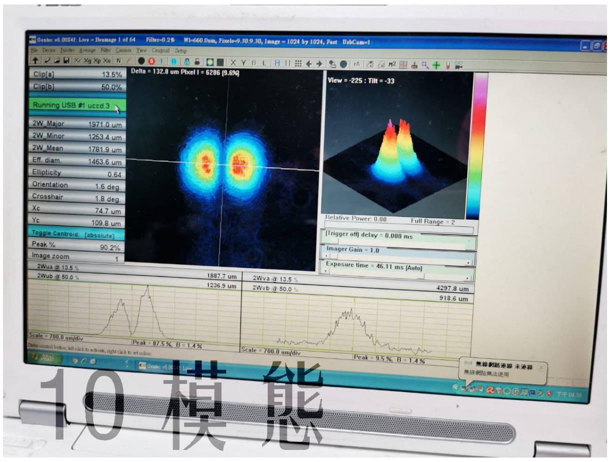
4 Transverse Modes

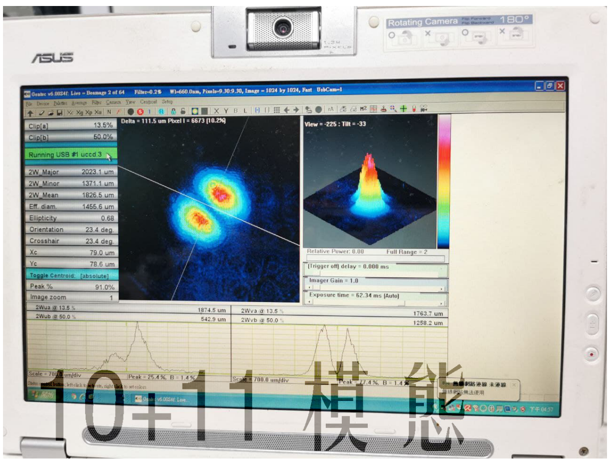
The transverse modes of a laser is the transverse (cross sectional) intensity profile of a laser beam.

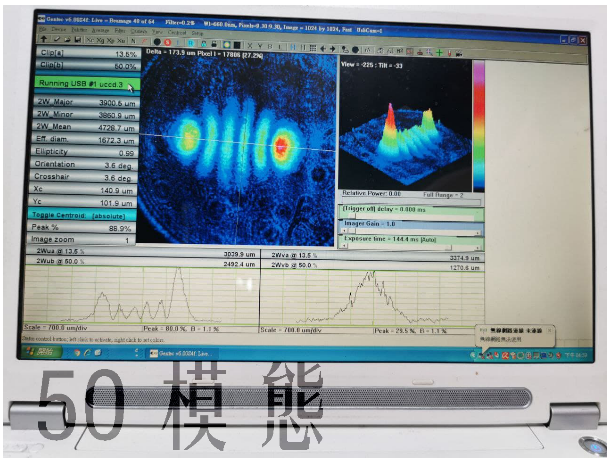
- (1). On the 3^{rd} mount, remove the aperture and put a green filter in its place.
- (2). Place a CCD on the laser path to observe the laser intensity.
- (3). Adjust the cavity mirror to break the alignment, and produce different transverse modes.
- (4). Observe and record the different modes obtained.

Record the different transverse modes.







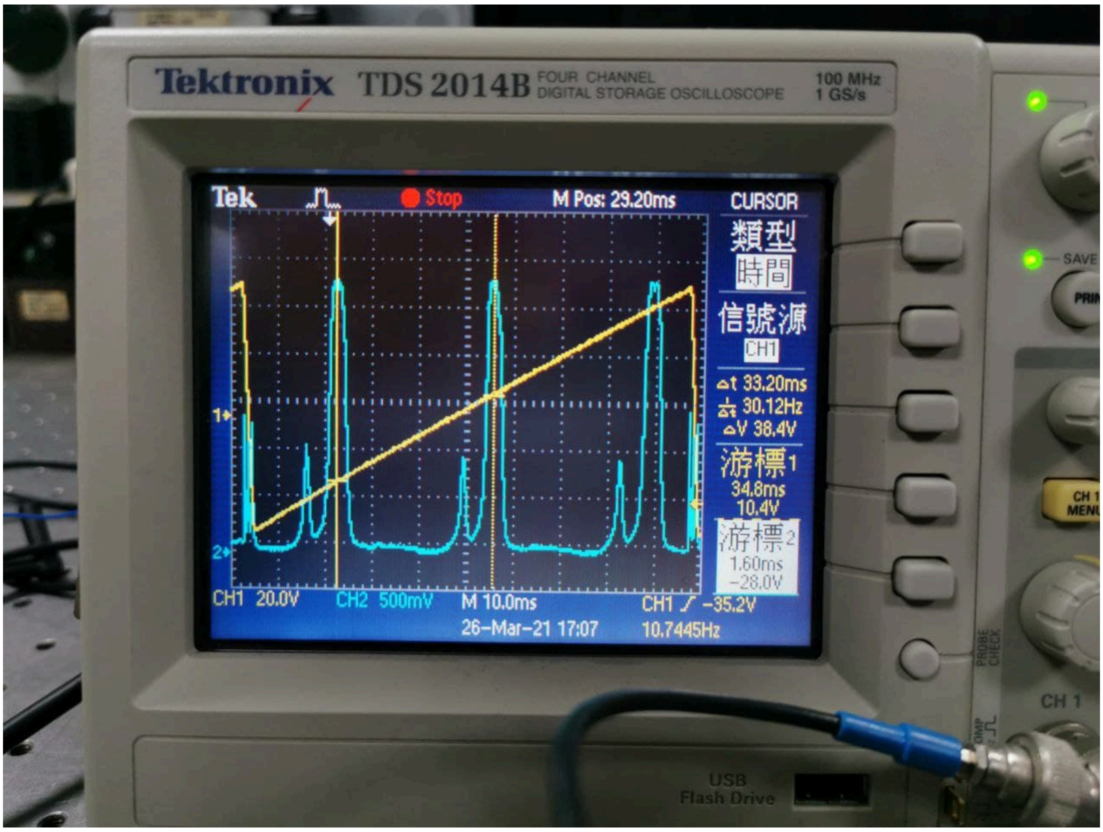


5 Longitudinal Modes

The longitudinal modes of a laser is the frequency (or wavelength) profile of a laser. A voltage driven scanning Fabry-Perot interferometer can be used to observe the profile.

- (1). Switch off the IR laser.
- (2). Turn on the He-Ne laser, the oscilloscope, and the scanning Fabry-Perot interferometer.
- (3). Place (and align) the scanning Fabry-Perot interferometer on the optical rack, in the path of the laser beam.
- (4). Adjust the settings on the oscilloscope to display 2∼3 periods of the frequency profile, make sure that the voltage signal can be seen clearly.
- (5). Observe, and take a photo of the frequency profile of the laser on the oscilloscope.

Photo of the oscilloscope.



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6 Post-Experiment Question

- Why does changing the cavity R affects the laser output power and thresh-old current?
  Reflectance愈高，光能在共振腔内的反射次數愈多，經過增益介質的次數較多，因此功率較高。不過相對的，起始電流也會愈大。
  當然，Reflectance不能是100%，這樣就不會有雷射輸出。

- High reflectance R means lower transmittance T (=1-R), which means a lower fraction of light inside the cavity can be transmitted out. So why does having higher cavity R **increase** the output power, but not decrease it? (**Bonus**)
  因為reflectance高的話代表雷射光在裡頭反射的次數增加，如95%R的雷射反射次數的期望值為20次，90%R的雷射僅有10次，而反射率低也代表回饋至雷射共振腔的回饋較小，增益介質所能帶來的效果也較小，因此輸出的雷射功率較小。

- Laser light is inheritantly polarized. Why does light inside optical crystals (e.g. the SHG crystal) behave differently, at different polarization directions? (Hint: crystalline structure)
  晶體内部都有所謂的光軸，如果入射光的偏振方向與光軸垂直，則入射光就會表現得像射入一個折射率固定的晶體一樣，反之，折射率就會隨著入射光與光軸夾角的不同而改變。

- One mirror of the scanning Fabry-Perot interferometer is voltage driven, moving a certain distance d given a certain applied voltage V. According to the experiment result (i.e. the photo of the oscilloscope), **how much distance d will the mirror move**, when $100V$ is applied?
  由圖中可知，讓強度從一個峰值到另外一個峰值的電壓，是38.4V，而這時鏡面移動的距離，剛好就是雷射波長的一半，也就是316.4nm。因此100V造成的移動量，就是823.96nm。

- According to the experiment result, the He-Ne laser also outputs wavelengths around its central wavelength 632.8 nm (the many spikes in the photo). How can **another optical cavity** be used to eliminate the other "unpure" wavelengths? (**Bonus**)
  根據駐波結構，要能產生那些光譜的結果要符合半波長的整數倍，如果想要消除其他非理想的波長，只需提供不同cavity然後讓特定的波長留下來，經過多次的篩選則可留下我們希望的結果。