XXI Studencka Sesja Plakatowa

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Laser Nd: YAG

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Abstract

In this experiment we are going to use a modular Nd: YAG laser to learn the basic of laser light generation. The main purpose of this experiment is to study the dependence of the output power of our lasing with the pumping power in several setups. We will also find the dependence with the outcoupling mirror transmissivity. The final goal is to determine the waist and the beam divergence of our beam using the knife edge method.

Experiment

At the first stage (after determining the dependence between the current and the pumping power), we built our optical cavity using the pump diode, the Nd: YAG crystal and a spherical mirror ($R = 90\%$) and we can measure the power dependence using the powermeter. Then, we replace the spherical mirror by the PBS, the QWP and a flat high reflecting mirror, as is shown in Fig.1, to determine the optimum output transmissivity. To study the second harmonic generation power, we put the KTP crystal as an outcupling mirror at a few of mm to the Nd: YAG crystal. Finally, we determine the waist of our beam with the so called *knife edge method*.

Theoretical Equations

The LASER (Light Amplification by Stimulated Emission of Radiation) is based on the creation of spatially and temporally coherent light. We achieve this by stimulated emission inducing a photon cascade, all the photons with the same energy proportional to the frequency:

$$(1) E = h\nu$$

For this process to be the most likely we need to have a system with inversion of population. To achieve it we pump photons from the ground state to the excited states in a three or four level systems. The condition that guarantees the stability of our cavity is:

$$(2) \quad 0 \leq \left(1 - \frac{L}{R_1}\right)\left(1 - \frac{L}{R_2}\right) \leq 1$$

Our laser beam is a Gaussian beam, therefore the transversal intensity distribution I of this mode is given by Gauss function:

$$(3) \quad I = A_0 e^{-\frac{2r^2}{w^2}}$$

Using the knife edge method, the variation of the width with the distance can be fitted as:

$$(4)\ w = \frac{w_0}{z_0}(z_0 - z_1)$$

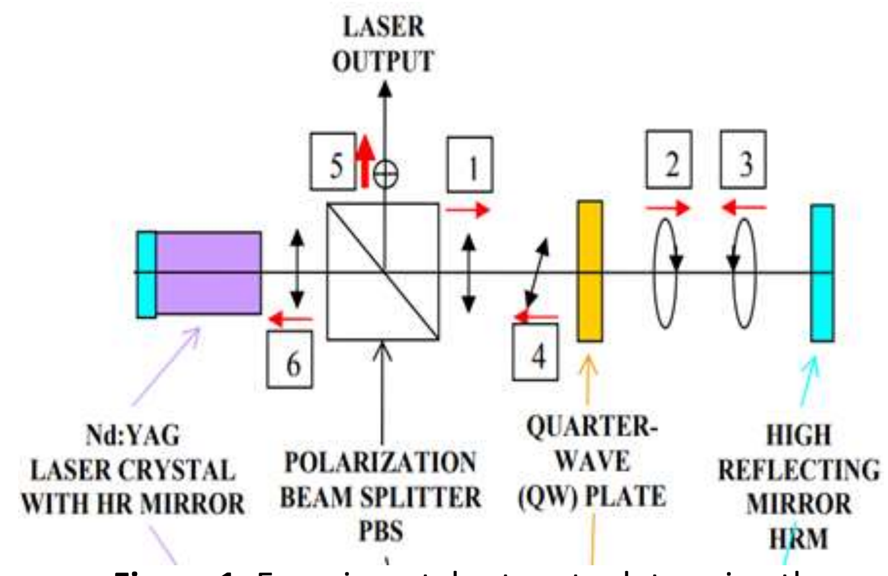

Figure 1. Experimental setup to determine the optimum output transmissivity.

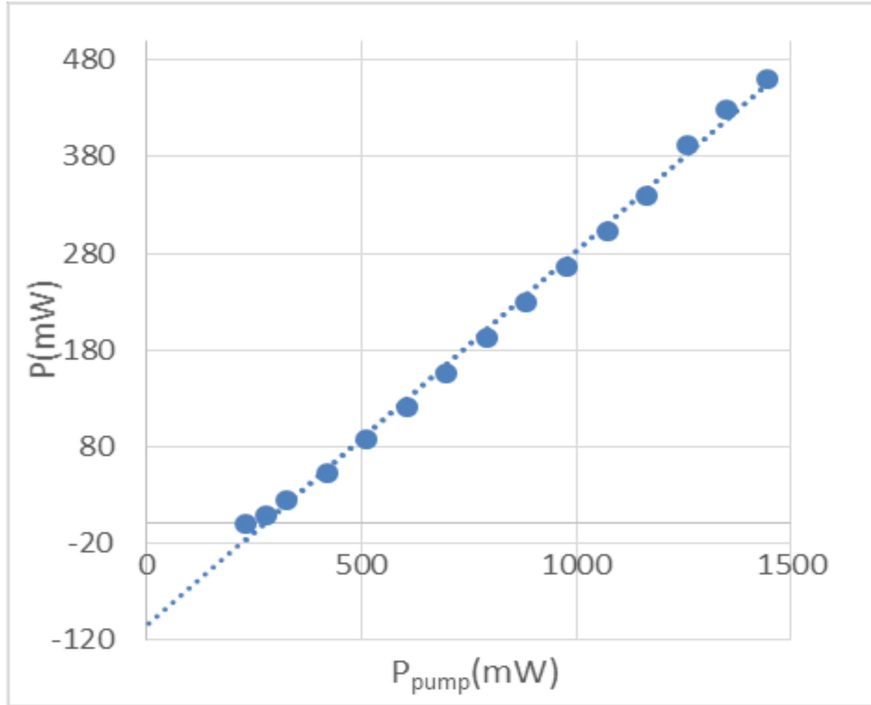

Figure 3. Dependence of the Nd: YAG laser power and the pump power.

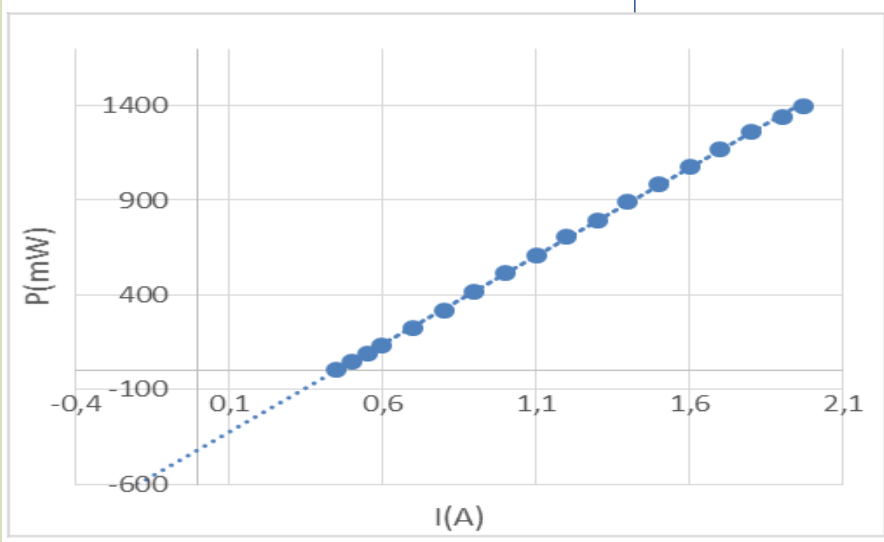

Figure 2. Dependecne of the pumping diode power and the current-

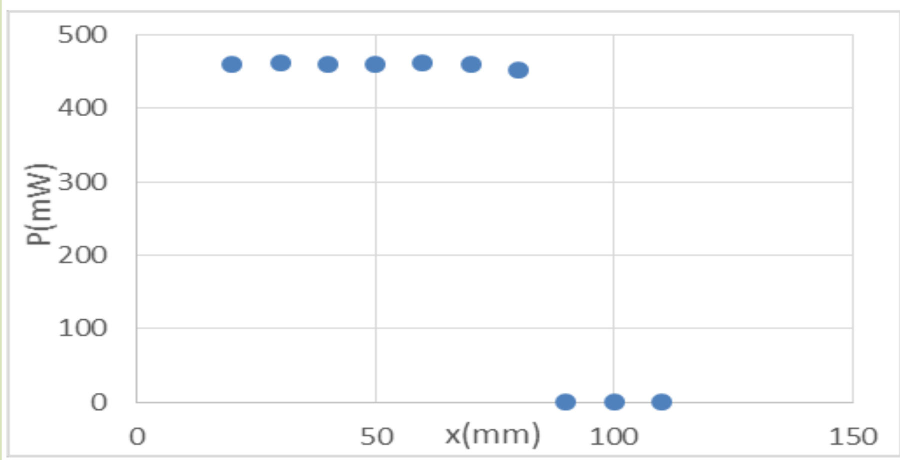

Figure 4. Verification of the stability region.

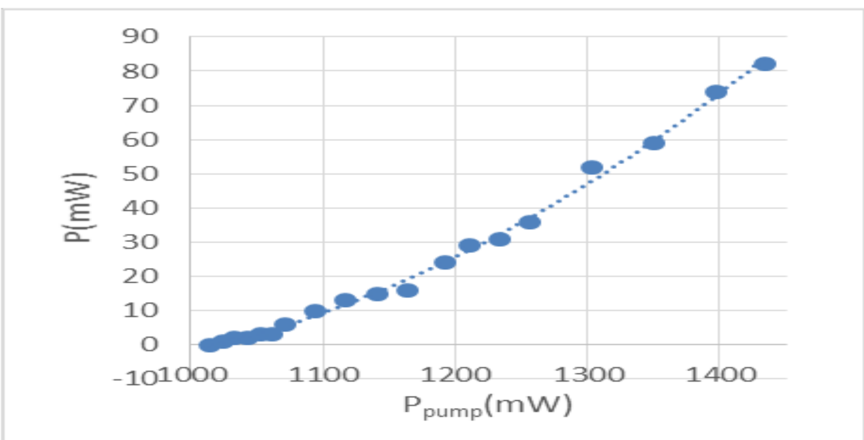

Figure 5. Dependence of the SHG power with the pumping power.

Data Analysis

As we can observe, we obtain a linear dependence of the pumping diode power with the current (Fig.2), as we can theoretically expect:

$$\boldsymbol{P(mW) = (930,8 \pm 4,1) \cdot I(A) - (418,7 \pm 7,2)}$$

Using this relation, we obtain the dependence of the Nd: YAG laser power and the pumping power (Fig.3). As we can observe, this dependence has a threshold after which it quickly changes to a linear dependence:

$$\boldsymbol{P_{laser} = (0,388 \pm 0,13) \cdot P_{pump} - (107,2 \pm 7,1)}$$

In the Fig.4, we can verify the conditions of stability of our cavity. Using (2) and due to $R_1 \to \infty$ *and* $R_2 = 80mm$, the length of the cavity should be $\boldsymbol{L \leq 80mm}$, as we can observe in the plot.

Then, with the KTP crystal, we were able to check the quadratic dependence of the second harmonic generation power with the pumping power (Fig.5):

$$\boldsymbol{P = (8,04 \cdot 10^{-5} \pm 0,43 \cdot 10^{-5}) \cdot P_{pump}^2}$$

Using the setup shown in Fig.1, we can measure the power for several angles that we can set in the QWP. Then, using this relation, we can observe the dependence between the output laser power and the transmissivity, as is shown in Fig.6.

Finally, using the knife edge method (Fig.7) and (4) we obtain the value of the waist of our beam:

$$\boldsymbol{w_0 = 0,821 \pm 0,025\ \mu m}$$

We can consider this value satisfactory regarding to the characteristics of the laser and the size of our setup.

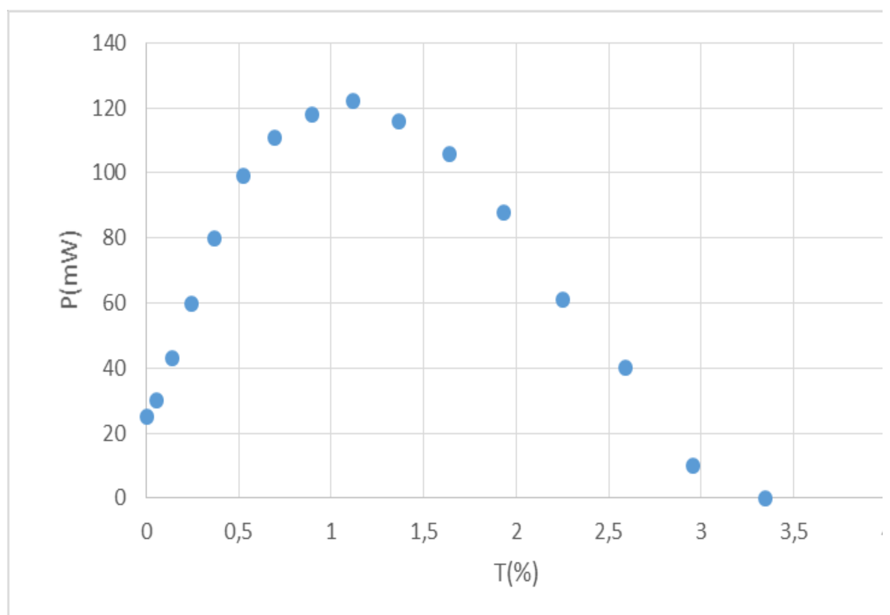

Figure 6. Dependence of the outcupling power and the transmissivity.

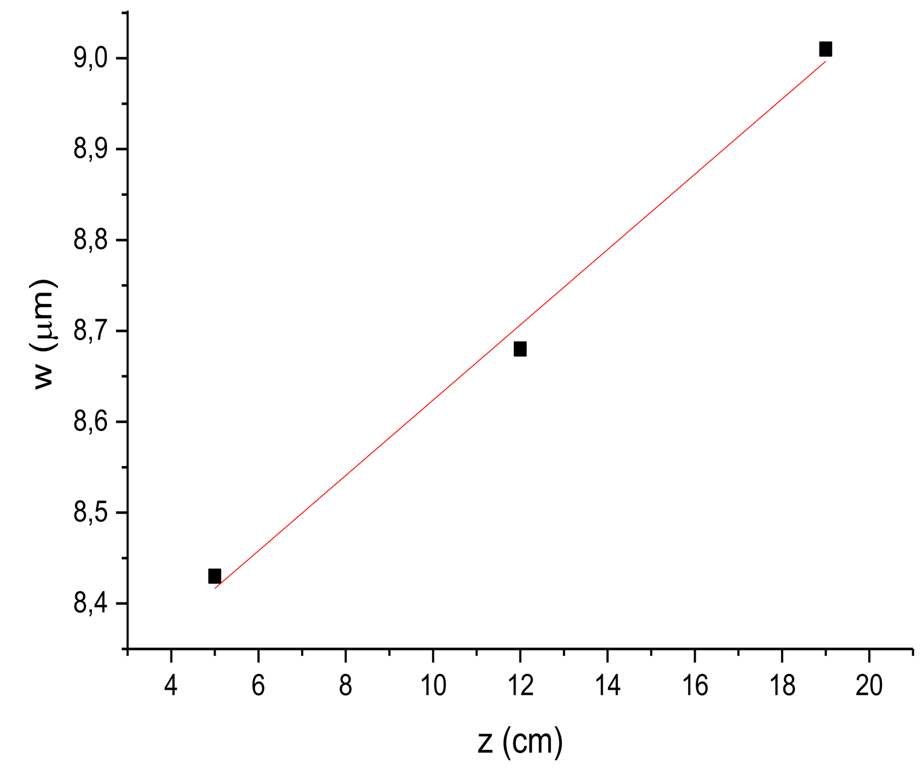

Figure 7. Dependence of the width of the beam with the axial position.

References

[1] *Basic Laser Theory*, provided by the USOS web.
[2} Feynman, R. P., Leighton, R. B. and Sands, M. (1963). The Feynman Lectures on Physics, Volume 1. United States of America: Addison-Wesley[5]
[3]Manual for the experiment Z16 (www.2pf.if.uj.edu.pl).