Alignement of a ring cavity laser

1 Introduction

This manual describes a procedure to align the cavity of our Ti:Sapphire ring laser and its injection with an Argon-Ion pump laser beam. The setup is shown in figure 1. An 8 W Argon-Ion pump beam is adjusted in size and degree of divergence by a telescope consisting of a 62 mm and an 88 mm lens (L1 and L2). A periscope (mirrors P1 and P2) and a collimation lens C (f=175 mm) is used to inject the 500 nm Argon-Ion beam into the ring cavity. The cavity itself consists of the curved entrance mirror M1, a second curved mirror M2 (both f 100 mm), and two flat mirrors M3, and M4. The latter is the output coupler. All mirrors are optimized for 850 nm. The cavity laser is circling in the vertical plane. The Ti:Sapphire crystal is placed at an angle of 30° to the vertical and has flat horizontal entrance and exit surfaces. The crystal is pumped by the Argon Ion laser beam and emits fluorescence light in the red and infrared. The direction of circulation of the infrared light is given by an optical diode between M4 and M1. The frequency is chosen by adjusting a birefringent filter between the diode and M1.

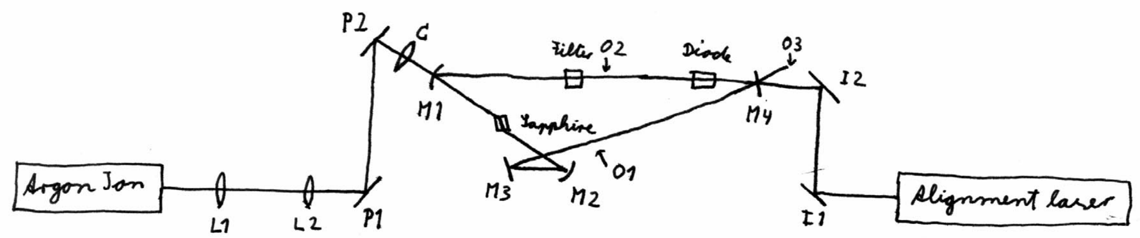

Figure 1: Setup of the Argon Ion pumped Ti:Sapphire ring cavity laser.

The procedure described in the following assumes that the optical elements are already approximately at their final positions and especially that the distance between the two curved mirrors has been regulated, such that an initially collimated infrared beam entering M1 in the sense of the cavity ring exits M2 still collimated. The alignment procedure follows in several steps, each of which increases the precision with which the elements reached their final position.

2 Alignment of the cavity using an alignment laser

An infrared diode laser was used for a first alignment of the cavity. If no such laser is at disposition, you might try to go directly to the alignment of the Argon Ion beam using the technique described below. If the cavity is not too misaligned, this can work. We used a 780 nm laser, resulting in a cavity which is slightly disaligned for the final 850 nm laser light due to the difference in index of refraction of the different optical elements (mainly the Ti:Sapphire) for different wavelength. The alignment is done as follows. Using two external mirrors I1 and I2, the beam is aligned to the middle of the output mirror of the ringcavity and its direction is aligned such that the beam goes through all the optical elements of the ring cavity and hits the output mirror again at about the same spot. To verify this alignment the "paper with hole technique" is used. This technique uses a paper which has a 4 mm diameter hole punched into a corner. The border is about 1 mm large. The incoming beam is made to pass through the hole. If the beam that passes once through the ring cavity is slightly missaligned, it will not pass again through the hole, but hit the paper. This can be checked by moving the hole around the incoming beam and partially blocking it. (*) Now the beam is by purpose disaligned in the vertical direction using the input mirror M1. This gives two clearly visible spots on the paper, when the incoming beam is only half covered by the hole. The real sizes of the beams is estimated by moving the paper. Now the beams can be well aligned in the horizontal direction using M1h. Now the beams are approached to each other vertically (M1v) until they touch. The position of M1v is marked. The beams are moved farther in this direction. They merge and later two distinct beams reappear. If a situation symmetric to the first is reached M1v is marked. Now M1v is brought to the middle position between the two marked ones. Using this method, the beam should hit its initial position at the output mirror M4.

Next M4 is adjusted to allow the beam to pass a second time through the cavity. Again the paper with hole technique is used. Since the beam will have weakend, an IR viewer is used to see it. The beam making the second passage is observed during its passage through the cavity, first near the output mirror and then farther away. If it diverges too far from the beam making the first passage, M4 is adjusted. To facilitate the identification of the beam making the first or second passage, the is interrupted periodically just before rereaching M4 inside the cavity. This makes the first passage beam spot appear steady, while the second passage spot blinks. Just before reaching the end of the second passage, which means about halfway between M3 and M4, a precise alignment is performed using the method described above (*) but using M4.

Now an interference pattern should be observable at the infrared beam exiting through the output mirror M4 under an angle O3. M4 can now be adjusted to center the interference rings on the center of the beam. Now the cavity is very well aligned for the frequency of the alignment laser, in our case 780 nm. For 850 nm the cavity will be off by about 1 mm after one round trip in the vertical direction due to the difference in index of refraction of the Ti:Sapphire crystal for the different wavelength (500 nm: n=1.775; 780 nm: n=1.76; 850 nm: n=1.758, see I.H. Malitson J. Opt. Soc. Am. 52, 1377 (1962)). This has to be taken into account by adjusting the vertical direction of M4 by that amount, which in our case moves the center of the interference fringes upwards by about one millimeter, just out of the beam.

3 Alignment of the pump beam

For alignments which do not require the observation of fluorescent light coming from the Ti:Sapphire crystal, the Argon Ion beam is regulated to about 10 mW. The telescope (L1, L2) is adjusted such that a collimated beam is produced. The periscope (P1, P2) is used to center the beam on the crystal and on mirrors M1 and M2. The beam dump is regulated to catch the beam. A crude but sufficient method to position the focus of the beam inside the Ti:Sapphire crystal is to increase the beam power to 8 W and observe the convergence and divergence of the beam as it goes from M1 through the crystal to M2. The beam is visible to the naked eye because it scatters off dust in the air. The telescope (or lens C) is adjusted until a symmetric situation is reached. (For all other manipulations of the 8 W beam, appropriate filter eye goggles are recommended.)

Now the power of the beam is brought back to 10 mW and is aligned with the infrared alignment beam by observing the beams at two distant points between M3 and M4 and regulating P1 for the point near to M3 and P2 for the point near M4. Especially the alignment in the horizontal direction has to be done carefully. The vertical direction is not as important as the fluorescence light has to be used for this due to the difference in wavelength and thus refraction.

The beam power is brought back to 8 W. An IR filter, blocking all green blue light from the Argon Ion is attached in front of the IR viewer. The goal is now, to align the fluorescent light coming out in both directions from the crystal onto the alignement laser. For this the beam is observed at two places in the ringcavity: O1) after M3, right after the passage of the hole through the holder of M4 and O2) after the birefringend filter in direction towards the diode. The images show three beams: the fluorescence coming out in the forward direction of the crystal (copropagating with the Argon Ion) B1, the fluorescence coming out in the backward direction of the crystal B2, and the alignment laser B3. B3 can be identified by blocking the beam at the output of the alignment laser. B1 and B2 can be identified by blocking the respectively other beam at the opposed observation position (O1 for O2 and the inverse). In the horizontal direction all three beams should already be perfectly aligned at both observation positions. If not, the cavity is not aligned properly or the Argon Ion beam is not aligned properly on the alignment laser. In the vertical direction the beams should be offset. This is due to the fact, that the Argon Ion beam with its 500 nm was aligned to the alignment beam. The infrared fluorescence will exit the crystal with an angle of about

1.2° to the Argon Ion beam because of the difference in index of refraction. The following procedure compensates for this. Using the vertical direction screws of P1 and P2, the three beams are brought to overlap as well as possible at both observation positions (O1, O2). Special care has to be taken to assure that B1 and B2 always at least partially overlap. The result should look as in figure 2.

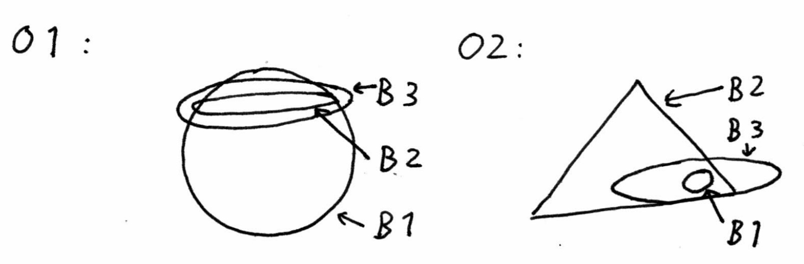

Figure 2: Superposition of the infrared beams in the cavity.

4 Alignment of the cavity to the fluorescence

This alignment nearly closes the cavity for the infrared fluorescent beams. But, at least when the cavity is aligned perfectly for the 780 nm radiation, it is not completely closed for the fluorescent beams. To achieve this, the paper with hole technique is used a last time. The alignment laser is blocked. The observation is done at O1 using the IR viewer. Most of the fluorescent light B1 is passed through the hole. By moving the hole up and down, a tiny little weak spot is searched that appears and disappears in dependance of the position of the hole (see figure 3). This spot results from fluorescent light B1, that travels around the cavity, a second time through the crystal and comes back to the paper. Using the vertical screw of M4 this spot is brought in superposition with B2 at O1. This should also result in a shift of the interference fringes of the alignment laser at the output window, similar to the one described above.

5 Starting the laser

Now the laser should be nearly aligned. The IR filter is fixed in front of the sensor of a power meter. The sensor is placed at the output of the Ti:Sapphire laser. The power meter is set to the most sensitive range and its offset regulated to zero while blocking the upper cavity path. Now the optical elements of the input beam are touched (no screws are turned yet!). The slight movement of the elements by just touching them

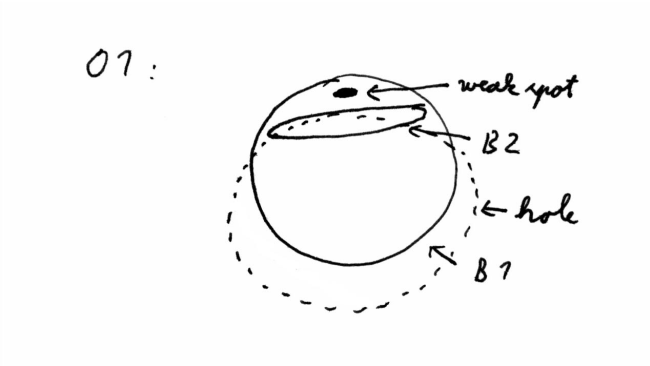

Figure 3: Search for the fluorescence beam after one roundtrip through the cavity.

might get the laser to work. If this is not the case, the periscope mirrors P1 and P2 are regulated in the vertical direction. A two dimensional search is performed with the screws P1v and P2v (one moved fast forward and backwards, while the other moves slowly). The range of movement should not exceed about one tenth of the turn of a screw. At this point you can expect the needle of the power meter to jump up, indicating a working laser. If no such point is found, M4v should be turned a little and the search started again. If this isn't sufficient, also the horizontal degrees of freedom are taken into account, or the whole alignment procedure is started from the beginning.

When a position is found at which the laser lases a bit (which shouldn't be too difficult at that point), all screws of all optical elements can be realigned to optimize the output of the laser. Be careful to remember always what you do, so that you can easily undo it, if you loose the laser.

6 Conclusion

This alignment procedure was given specific to the Argon Ion pumped Ti:Sapphire laser system used in the biological optical neuron guiding group of Mark Raizen at the university of Texas in Austin. It is expected that it is useful for many ring cavity lasers of similar type of construction.

Florian Schreck and Samantha Moore, Austin, 5/25/2002, with thanks to Windell Oskay and Mark Raizen.