Building a contrast monitor for TAW

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Introduction

In facilities such as Vulcan, the amplification process produces unwanted effects. One of the most noticeable effects is Amplified Spontaneous Emission (ASE). This effect has direct impact on the achievable gain of a medium, and thus on the final power available. The noise created has a level of approximately $N*G*\Delta\omega*ђ\omega$, where N is the number of modes, G the gain, $\Delta\omega$ the amplification bandwidth and $ђ\omega$ the energy of the photon. Despite the vast array of diagnostics available in Target Area West (TAW), there is nothing capable of monitoring the contrast and noise created by the ASE.

The contrast monitor

The principle of a contrast monitor is rather simple. The contrast is the ratio of the peak power of the pulse against the maximum noise level.

In Target Area Petawatt (TAP), the contrast monitor is composed by a photodiode using a leak and an oscilloscope. In TAW, such a configuration is not possible, as there are two other sources of noise, other than ASE, created by the experiment. The first is a pure optical noise, caused by all the light inside the room which completely dazzles the signal incident on the photodiode. This is easily solved by only allowing the input of the photodiode to be the incident beam. The second and most detrimental form of noise is electrical. When the laser is fired on target in TAW, a large amount of electrons and X-rays are emitted. In addition to this, we have electron magnetic impulses that are created during the experiment, adding another electrical noise. As the oscilloscope is not shielded against this radiation, the signal from the laser pulse is swamped by the electrical noise produced. This can be solved by placing the contrast monitor away from TAW, so it is shielded from the radiation.

The solution to these two problems is found with fiber optic cable. This would allow us to couple the light from the beam, not the background light while it would permit us to transport the signal wherever we want, in this case inside a radio protected area.

The fiber

Nevertheless, the use of fiber optics has its problems. The direct injection of the beam would lead to instant damage, as the fiber damage threshold is 10^9 Wcm^{-2} for mono mode silicate fiber. Therefore, the peak power of the beam must be reduced before coupling into the fiber. An easy and cheap way to do so is to lose energy inside a medium such as water. By focusing the beam inside water, an intensity of up to 10^{16} Wcm^{-2} can be achieved, which is well beyond the ionization threshold of water (approximately 10^{12} Wcm^{-2}). The refractive index of the created plasma will be of the order: $= 1 - \sqrt{\frac{ne}{nc}}$, where ne is the local electron density and nc, the critical electron density. The critical electron density is dependent on the frequency of the beam, $\omega^2 = 4*\pi*e^{2}*\frac{nc}{m}$, where m is the mass of the electron. Locally we have ne > nc, switching the index of the plasma from real to imaginary. As a consequence the beam wouldn't propagate into the plasma and would act as a mirror. It is hoped that the plasma achieves this partially, thus allowing a proportion of the beam to propagate, while the others part of the beam can be diffracted, absorbed or send back.

Also, to avoid any dispersion issue, we will be using a monomode fiber.

Pre pulse signal

As the signal rises until the photodiode is saturated, it becomes unclear where the peak of the laser pulse arrives. To know this, a second signal is used as a reference. A reference pulse is tapped off from the original laser pulse. Using the fiber, a delay is added, separating the two signals by a known amount. As a consequence, of measuring the delay we can have the approximate position of the beam and its maximum peak value.

We then couple the signal from the pre pulse and the pulse inside a lone fiber and put it at the input of the photodiode to have a lone signal at this input.

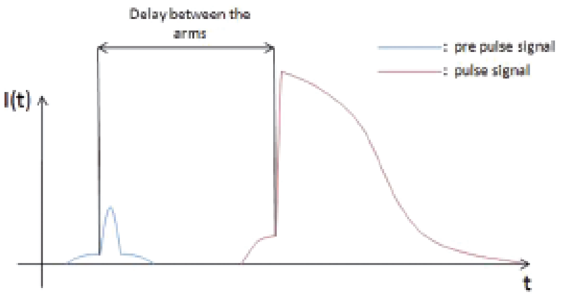

Figure 1. Expected signal on the oscilloscope.

Setup and test

The setup of the contrast monitor is simple. First, the alignment and the coupling of the fiber must be optimal.

For the alignment an aperture is used as a reference to check the parallelism of the beam. The coupling is harder as the monomode fiber core is between 8 to 10 µm and is achieved by maximising the signal at the output of the fiber.

The testing of the contrast monitor will be performed using a picosecond source, to allow us to check the behaviour of the device with a controlled signal.

Conclusions

In conclusion, we have managed to build a cheap contrast monitor. We still need to test it under real conditions, in particular to observe the behaviour of the photo diode and the efficiency of the overall device.

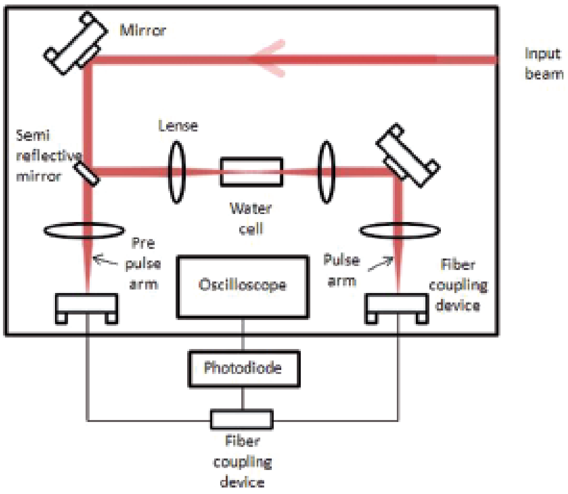

Figure 2. Layout of the contrast monitor.