Report of Zeeman spectroscopy experiment with magnetized silicon plasma

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Introduction

In this research we tried to measure Zeeman splitting in the soft X-ray range emitted from a magnetized silicon plasma produced by laser. Silicon is one of the abundant materials of the universe and Zeeman splitting is a measure of the magnetic field in astronomical observation. We used a capacitor coil target to generate a kilo-tesla level seed field and compress the seed field by laser driven implosion. According to hydrodynamic calculations, a peak field of 10 kT can be achieved on GEKKO-XII. This strength is close to what is found on the surface of a white dwarf. The X-ray spectrum measured in the laboratory will be compared with astronomical observations. This is also a technique for measuring very strong magnetic fields generated in the laboratory.

Experimental purpose

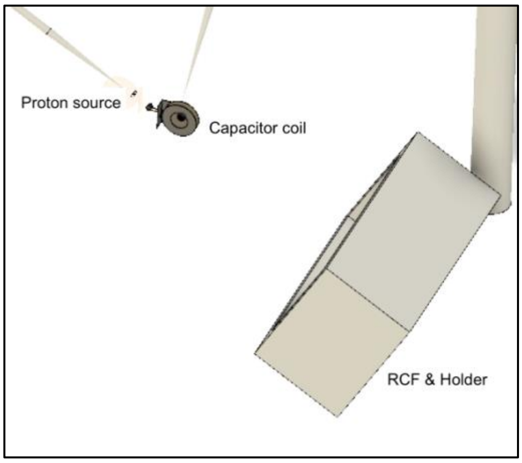
We focus on Zeeman spectroscopy of soft X-rays emitted from a magnetized high energy density plasma of 10 kT field in this research. The goal of this experiment design is to observe a nonlinear Zeeman effect in the laboratory. This is an important physics for determining the magnetic field strength from the astronomical spectrum. Silicon is one of the abundant materials of the universe. We intended to observe the change in the spectral shape emitted from the laser-generated magnetized silicon plasma in the soft X-ray region with changing the magnetic field strength. It is difficult to accurately calculate nonlinear Zeeman effect other than hydrogen and hydrogen like ion. The laboratory experiments are essential for identifying nonlinear effects in multi-electron atom systems. Based on our laboratory measurements, we try to find Zeeman splitting lines in astronomical data. This behavior may reveal how laboratory astrophysics contributes to traditional astronomical research.

Experimental design

According to the actual experimental arrangement, during the FO-03 experiment series target shots has been divided into 2 parts, which are magnetic-field measurements and the Zeeman effect measurements.

In the magnetic-field measurement experiment, we used a capacitor coil target as the main target, and an Al foil as the source of proton shadowgraph. The experiment schematic is shown in Fig. 1(a). The magnification of the image on the RCF is 15x.

In the spectra measurement experiment, two capacitor coil targets were used to generate seed field to compress a ~10 kT strength strong magnetic field. A SiO_2 foam (5 mg/cc) filled polyimide cylinder was placed at TCC as the main target. The spectra were observed by a EUV spectrometer. The experimental design is shown in Fig. 1(b).



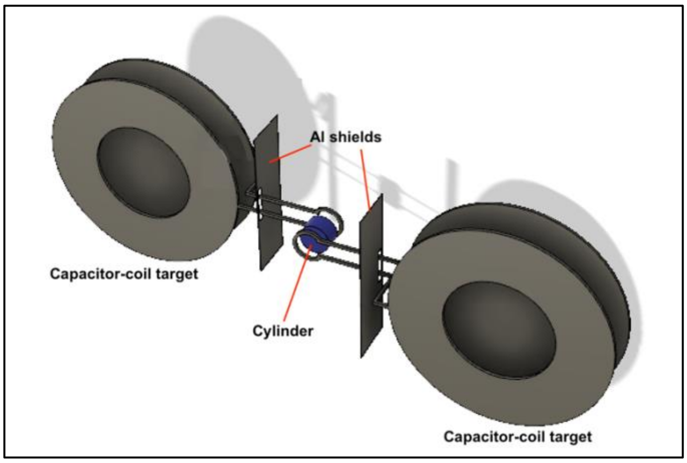


Figure 1 (a). B-field measurement (b) Spectra measurement

Experiment and preliminary results

The primary experiments were performed in two days 4 shots. The B-field measurement experiments were performed on 14th February and the spectra measurement are performed on 15th February.

In the experiments of B-field generation, with a LFEX time delay of 290 ps (~325 ps before the GXII implosion beams peak) we got a comb shape pattern on the RCF (Fig. 2), which indicate a existence of B-field. Simulations will be performed to estimate magnetic field strength in the future.

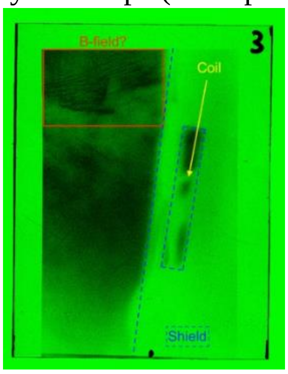


Figure 2. RCF result

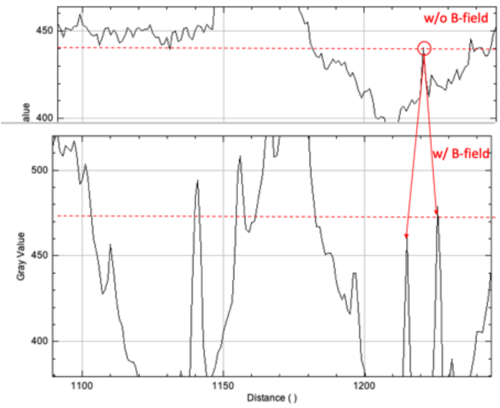


Figure 3. A probable splitting

We can find several probable Zeeman splitting peaks in the spectra measurement experiment. An example is shown in Fig. 3. A Roughly estimation of the peak energy is around ~80 nm. Next step we will try to calculate the plasma parameter, confirm the energy range of the potential Zeeman splitting lines, identify the elements and transitions. The comparisons between these lines, calculational and astronomical ones will also be done in the future.

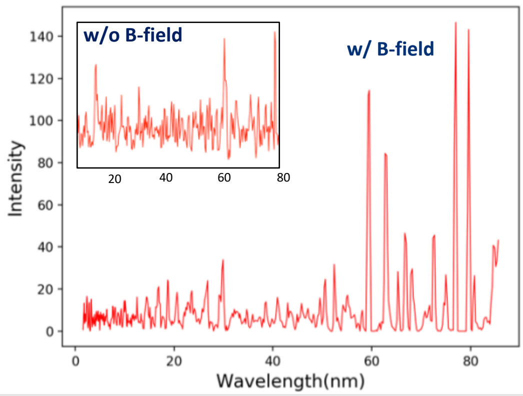


Figure 4 EUV data

In addition, the original spectral data there is a background noise. It makes some trouble to identify possible splitting lines. The noise is due to the instrument problems in the EUV spectrometer. However, it can be removed with FFT method (Fig. 4). The more detailed results will come out shortly.

Reference

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