DESY Summerstudent Programme 2009

Project Report

Line spectroscopy of samples heated by xuv free-electron-laser radiation

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Introduction

The objectives assigned for the summer student programme were:

1. Develop a Labview subVi to extract a 24bit FLASH bunch ID, 16 from a NI6535 and 8 from DOOCS.

2. Improve the user interface of a Labview software to control an oscilloscope and store data from it.

3. Analyze some data from a spectrometer, concerning BN and Si_3N_4 samples heated by xuv pulses from FLASH.

1 FLASH Bunch ID

The FLASH bunches are pretty different one from another. So when acquiring data is sometimes important to keep track of which bunch generated that.The characteristics are registered by the system and a sequential 32-bit ID is assigned to every bunch, but in our case just the 24 less significant ones are needed. To send to the computer the bunch id, a NI6535 I/O interface is used. It has a 32-pin port, and since 16 of them are wanted to be used for writing, 16 are left for reading. Here comes the necessity to recover the remaining 8 bits from somewhere else. A "ready to use" Labview subVi was then coded. It waits for the trigger, then reads from the I/O device the less significant 16bits, and the remaining 8 bits from the Ethernet from DOOCS, and merge them together.

2 Oscilloscope software

The scope-gui software is an interface to control an oscilloscope, save data, and analyze it. My second task was about solving two issues about the scope settings controls: the software actually was waiting for a trigger from the scope to change them and it was not possible to use them during acquisition. So an event-driven approach was used to solve both issues at once.

3 Data Analysis for line spectroscopy on BN and Si_3N_4 samples

My third task was about doing some preliminary data analysis on some 512x2048 images from a CCD detector. These images came from BN and

Si_3N_4 samples heated by xuv pulses from FLASH. In figure 1 there is an example of the image from the detector.

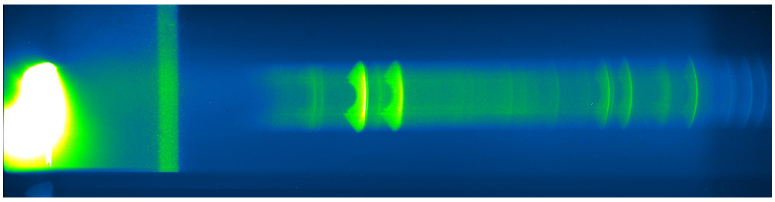

Figure 1: Example of image from the Si_3N_4 sample

As clearly visible from the picture the lines are curved and asymmetric due to the focusing devices. The first step was to get a good line spectrum from these images.

First, the background was subtracted, and then the symmetry of the image was exploited to find the center of the lines. That is, the point where the effect of focusing devices is less pronounced. There was some hopes that using just a very narrow central line one could actually get a lineout with gaussian enough peaks, but it turned out that was not the case. So a compromise between statistics and relative low asymmetrical effects was used for the line width.

The next step was identifying the lines. The comparison between BN and Si_3N_4 gives immediately hints on which the nitrogen lines are (figure 2).

Figure 3 shows the identified lines. All the details are taken from the NIST website. N IV and N V lines are present, as well as Si V ones. Also, there are a couple of lines neither from Si or N, probably some oxygen impurities.

The samples were moved away from the focus during the experiment, which means changing the energy deposited on the sample from xuv pulses and therefore the temperature. In figure 4 the spectra of Si_3N_4 on different positions are plotted, showing the line changes for every shot.

At this point, the temperature of the sample can be estimated from the ratio of the lines intensities for the identified transitions from the Boltzmann distribution as [1]

$$\frac{I_1}{I_2} = \frac{\omega_1}{\omega_2}\frac{f_1}{f_2}e^{-\hbar(\omega_1-\omega_2)/k_B T_c}$$

where ω and f are respectively the frequencies and the oscillator strengths of the lines. Nitrogen IV lines at 24.8 and 28.5 nm were used.

Results are given in tables 1 and 2. Notice that these are just rough estimates, and the error on them can go up to 1 eV or even more. A more raffinate analysis will be needed to obtain more reliable results.

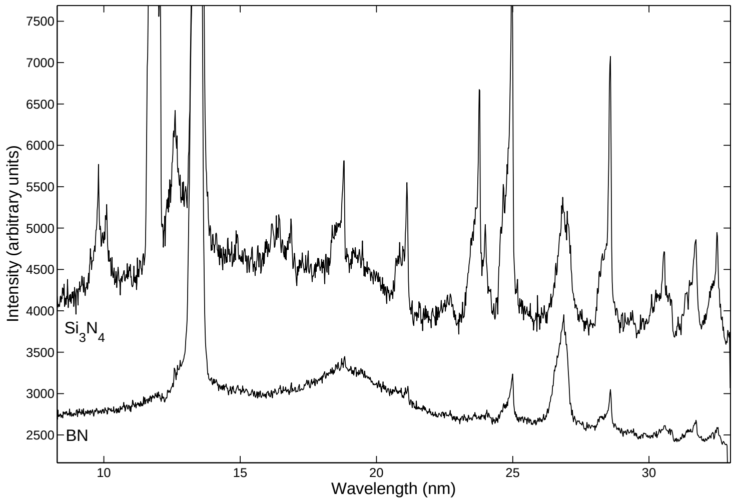

Figure 2: BN and Si_3N_4 spectra compared

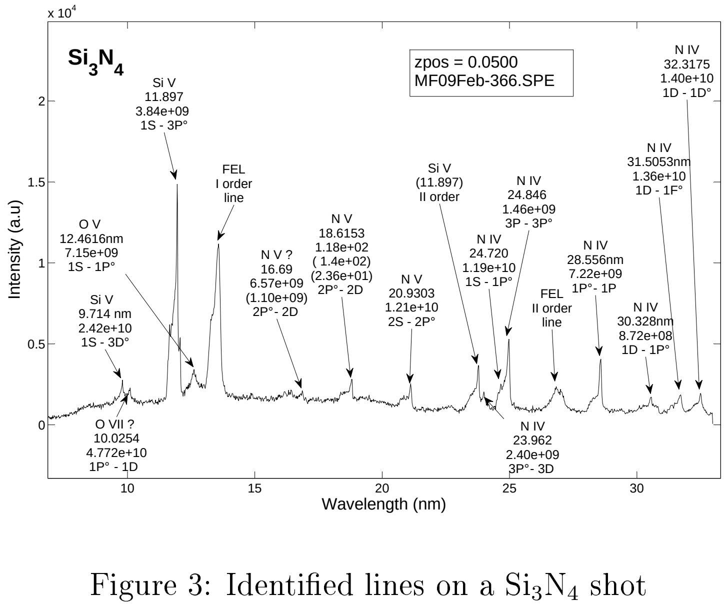

Figure 3: Identified lines on a Si_3N_4 shot

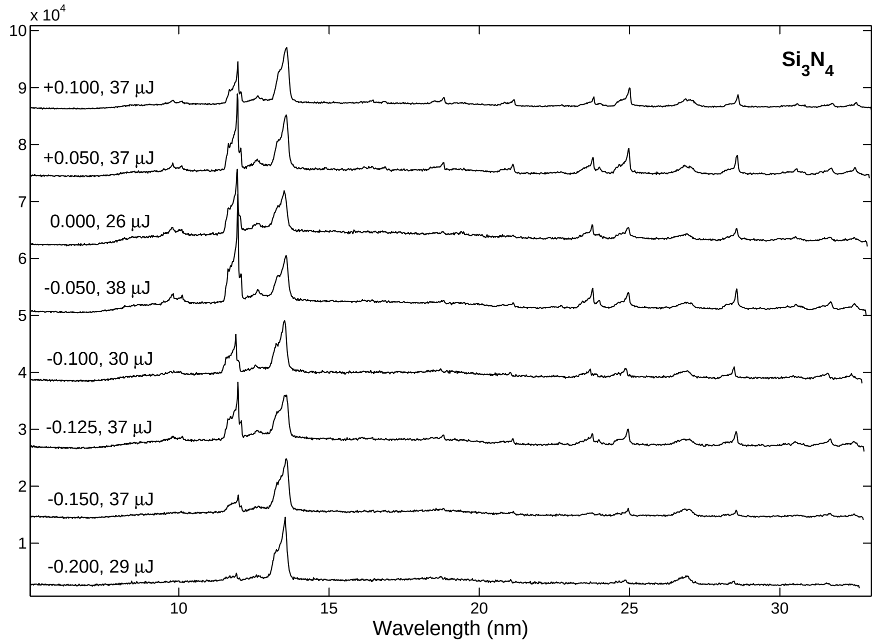

Figure 4: Spectra for different z-positions

zPos	**T$_c$ (eV)**
-0.100	7.4
0.000	6.7
0.075	4.7
0.100	4.4
0.200	4.8

Table 1: Calculated temperatures for BN

zPos	**T$_c$ (eV)**
-0.200	6.2
-0.150	6.5
-0.125	6.4
-0.100	8.9
-0.050	9.7
0.000	7.3
0.050	5.3
0.100	5.0

Table 2: Calculated temperatures for Si_3N_4

References

[1] Bremsstrahlung and line spectroscopy of warm dense aluminum plasma heated by xuv free-electron-laser radiation *Zastrau, U.; Fortmann, C.; Fäustlin, R. R.; Cao, L. F.; Döppner, T.; Düsterer, S.; Glenzer, S. H.; Gregori, G.; Laarmann, T.; Lee, H. J.; Przystawik, A.; Radcliffe, P.; Reinholz, H.; Röpke, G.; Thiele, R.; Tiggesbäumker, J.; Truong, N. X.; Toleikis, S.; Uschmann, I.; Wierling, A.; Tschentscher, T.; Förster, E.; Redmer, R.* Phys Rev E, 78 066406 (2008)