UCRL-ID-147990

Photometric Calibration of the SPREAD at the FTU Tokamak

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December 1, 1999

U.S. Department of Energy

Lawrence
Livermore
National
Laboratory

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This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Photometric Calibration of the SPRED at the FTU Tokamak

by

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Photometric Calibration of the SPRED Spectrometer at FTU Tokamak, Frascati Italy

The SPRED spectrometer was photometrically calibrated by using the FTU tokamak plasma and the Grazing Incidence Time Resolving Spectrometer (GRITS) from the Johns Hopkins University [Stratton, Nucl. Fusion, Vol. 24, No. 6, pp. 767-777, 1984]. The photometric calibration of the GRITS spectrometer was transferred to the SPRED [Fonck, R.J., Applied Optics, Vol. 21, No. 12, p. 2115 (1982)] by directly comparing the intensity of bright lines emitted from the FTU tokamak plasma that were simultaneously measured by both spectrometers. The GRITS spectrometer (λ = 10 - 360 Å; $\Delta\lambda$ ~ 0.7 Å) was photometrically calibrated in the 50 - 360 Å spectral range at the SURF II synchrotron light source at NIST in Gaithersburg MD in August 1997. The calibration of each SPRED grating was performed separately. These gratings covered the short wavelengths: 100 - 300 Å ($\Delta\lambda$ ~ 1.4 Å) and the long wavelengths: 200 - 1800 Å ($\Delta\lambda$ ~ 7 Å). This calibration should be accurate until the microchannel plate of the SPRED is exposed to atmospheric pressure. This calibration is similar to the one obtained by Stratton [Stratton, Rev. Sci. Instrum. 57 (8), pp. 204,3 August 1986].

I) The Short Wavelength Grating (100 - 300 Å)

The calibration of this grating was straightforward. The direct comparison of the intensities of bright lines measured by both spectrometers between 100 - 300 Å during the same plasmas were used to transfer the calibration. These lines consisted of intrinsic impurities and those of krypton gas that was puffed into the plasma during the November to December 1997 run period. For these measurements the SPRED's reticon integration time was 20 ms and microchannel plate high voltage was 800 V. This ASSUMES that the calibration in Show is normalized to 750 V. To adjust the calibration to 800 V divide by 2.5. The GRITS reticon integration time was 11.5 ms. The ratio of the intensities of each line measured by the GRITS and the SPRED are plotted in figure #1. The best fit to this data is the photometric calibration of the SPRED. The error in the GRITS photometric calibration was ±20%. The error in the SPRED calibration was calculated to be ±35%

The best fit to the data is:

$$\Gamma = 2.1995x10^{9}\exp(-0.0021901 * x) : R = 0.48$$

II) The Long Wavelength (200 - 1800 Å)

The photometric calibration of the SPRED's long wavelength grating was more difficult and had a higher inherent error. The calibration was performed in two steps. First, a series of bright lines emitted from intrinsic impurities and Ar puffed into the plasma were measured by both instruments in the region of spectral overlap (200 and 360 Å). The calibration in this region was obtained in a similar method as detailed above for the short wavelength grating. The photometric calibration was extended above 360 Å by using the line ratio technique. The line ratios chosen were the well understood $^2S_{1/2}$ - $^2P_{3/2}$ and the $^2S_{1/2}$ - $^2P_{1/2}$ s - p transitions in the Li and Na like iso sequences. These ratios should be ~ 2:1 in intensity. The actual theoretical ratios were calculated with the HULLAC atomic code. The SPRED measured these lines introduced by the laser blow off technique (listed in table) and those of argon. The GRITS spectrometer was not used in the extension to higher wavelengths. The calibration above 360 Å relied only on the relative sensitivity of the SPRED spectrometer. For these measurements the SPRED's reticon integration time was 20 ms, and microchannel plate high voltage was 700 V. This ASSUMES that the calibration in Show is normalized to 750 V. To adjust the calibration to 700 V divide by 0.4. This data was acquired during the November to December 1997 and the June to July 1998 run periods. The error in the calibration is ±35% at 300 Å and increases to about a factor of 2 at 1000 Å. The photometric calibration was the best fit to the data which is plotted in figure #2. The calibration beyond 1000 Å is an extrapolation of that below 1000 Å since no suitable emission lines existed above 1000 Å.

The best fit for the wavelengths above 470 Å is:

$$\Gamma = 10^{(a_0 + a_1 * x)} : R = 0.99$$

with coefficients:

Coefficient	Value
a_0	7.0849
a_1	0.0045025

The best fit for the wavelengths below 470 Å is:

$$\Gamma = 10^{(a_0+a_1x+a_2x^2+a_3x^3+a_4x^4+a_5x^5+a_6x^6)} : R = 0.99$$

with coefficients:

Coefficient	Value
a_0	15.649
a_1	0.035533
a_2	-2.2248e-5
a_3	4.0305e-7
a_4	-7.9951e-10
a_5	6.1911e-13
a_6	-1.6909e-16

III) MCP Voltage Calibration

The relative sensitivity of the SPRED was measured using FTU tokamak plasma as a light source. The SPRED measure lines with the low wavelength grating. The GRITS was measured the same lines (The Mo: 115.9 Å, 128.7 Å, O: 150 Å, Ni: 118 Å and Fe: 131.7 Å) simultaneously. During several plasmas the voltage was varied on the MCP of the SPRED. The relative sensitivity is shown in figure #3 and the best fit to the data is:

$$R = \left(\frac{1}{0.93628}\right)\exp\begin{pmatrix} -877.17 + 4.4627 * V - 0.0085316 * V^2 \\ +7.247x10^{-6} * V^3 - 2.3038x10^{-9} * V^4 \end{pmatrix}$$

IV) Wavelength Calibration

The fits to the wavelength in Angstroms as a function of pixel are shown in figure #4 and the fits are given by:

Low wavelength grating (100 - 300 Å):

$$Wave = 90.008 + 0.19213 * P + 4.0365x10^{-5} * P^2 - 1.6337x10^{-8} * P^3$$

High wavelength grating (200 - 1800 Å):

$$Wave = 199.82 + 1.3267 * P + 0.004371 * P^2 - 3.0212x10^{-7} * P^3$$

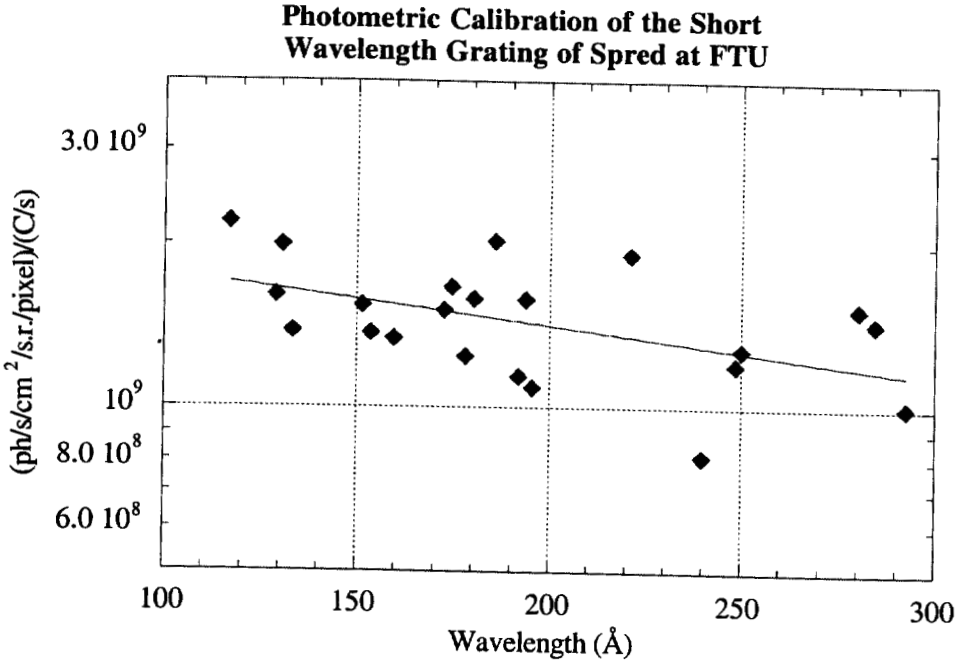

Figure #1

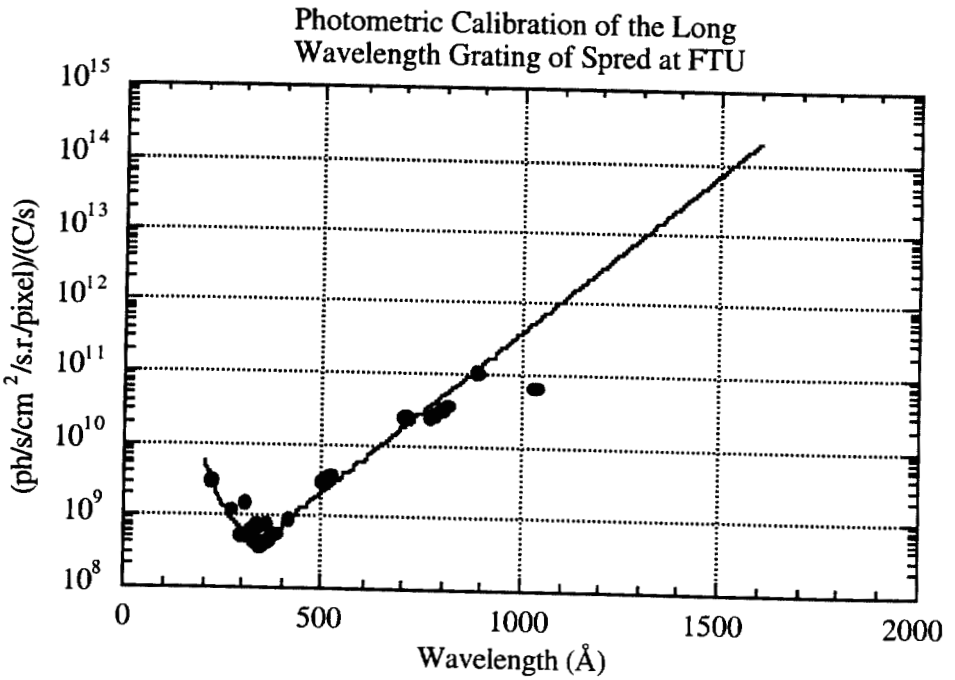

Figure #2

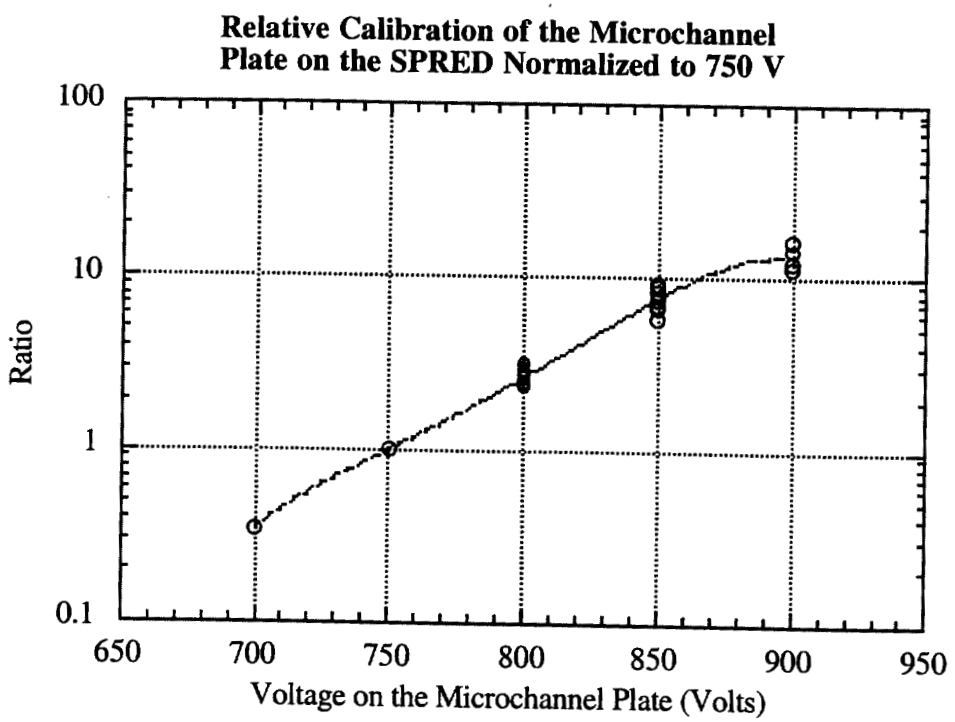

Figure #3

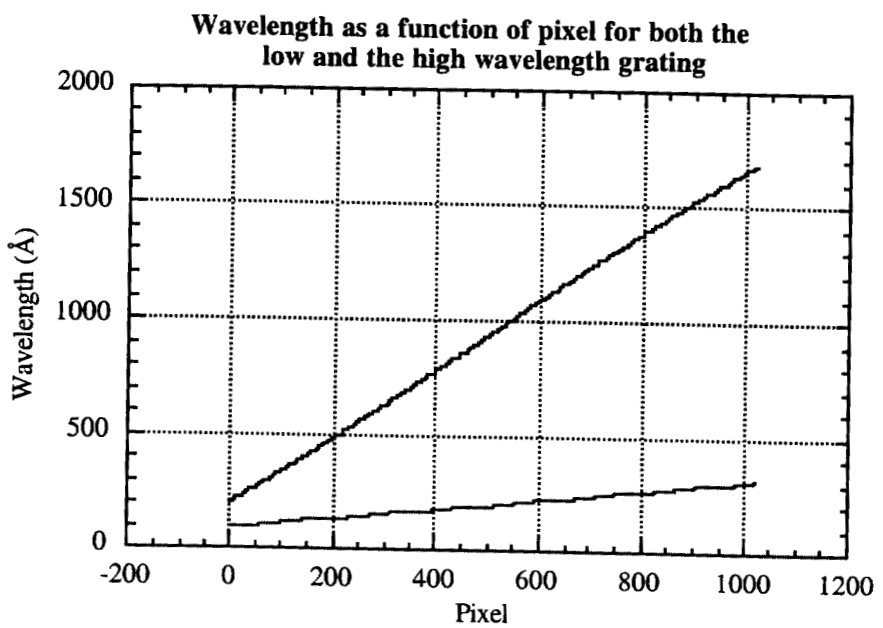

Figure #4

Charge State	Iso Sequence	Wavelength (Å) Transition (1/2 - 3/2)	Wavelength (Å) Transition (1/2 - 1/2)	HULLAC line ratios
Ni^{25+}	Li	164.42	234.20	1.84
Fe^{23+}	Li	192.07	255.09	1.87
Cr^{21+}	Li	223.0	279.7	1.89
Ti^{19+}	Li	259.296	309.104	-
Cu	Na	273.361	303.57	1.92
Ni^{17+}	Na	291.97	320.537	1.94
Ca^{17+}	Li	302.2	344.8	1.97
K^{16+}	Li	326.72	365.66	1.94
Fe^{15+}	Na	335.407	360.797	1.96
Ar^{15+}	Li	353.92	389.14	1.90
Cl^{14+}	Li	383.96	415.5	1.96
Cr^{13+}	Na	390.81	482.2	1.96
Ti^{11+}	Na	460.741	478.881	-
Si^{11+}	Li	499.40	520.67	1.98
Ca^{9+}	Na	557.8	574.0	1.94
K^{8+}	Na	621.452	636.325	1.96
Ar^{7+}	Na	700.245	713.812	1.94
Ne^{7+}	Li	770.409	780.324	1.99
Cl^{6+}	Na	800.64	812.64	1.98
F^{6+}	Li	883.1	890.8	1.99
O^{5+}	Li	1031.924	1037.614	1.99
Si^{3+}	Na	1393.755	1402.770	-

Wavelengths of the s-p transitions in the Li and Na like iso sequences used in the calibration of the long wavelength SPRED grating.