SAND2007-5057C

Slit Imaging Studies of Plasma Spray Plumes

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Org. 1813 - Thermal Spray Research Lab

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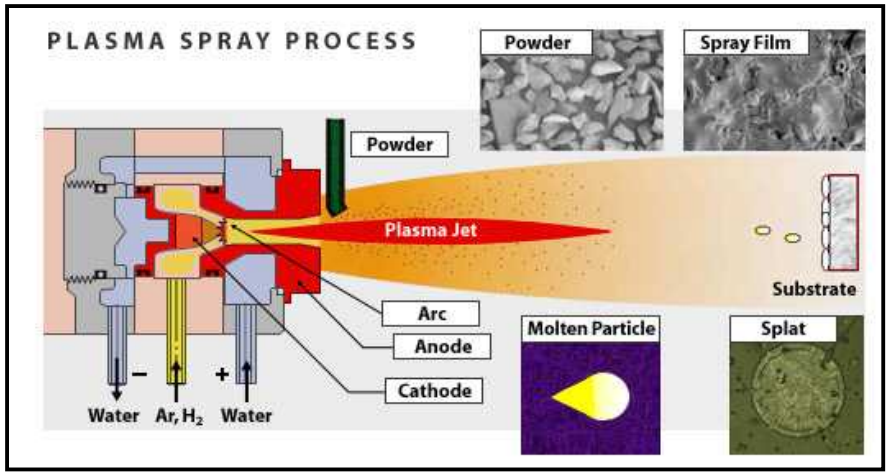
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Project Goal

- **Develop thermal spray diagnostic technique**
  - **Calculates radial temperature and particle density distribution**
  - **Can be calculated and analyzed with one measurement**
  - **Can be applied to a variety of thermal spray systems (i.e. flame spray, low pressure-plasma spray)**



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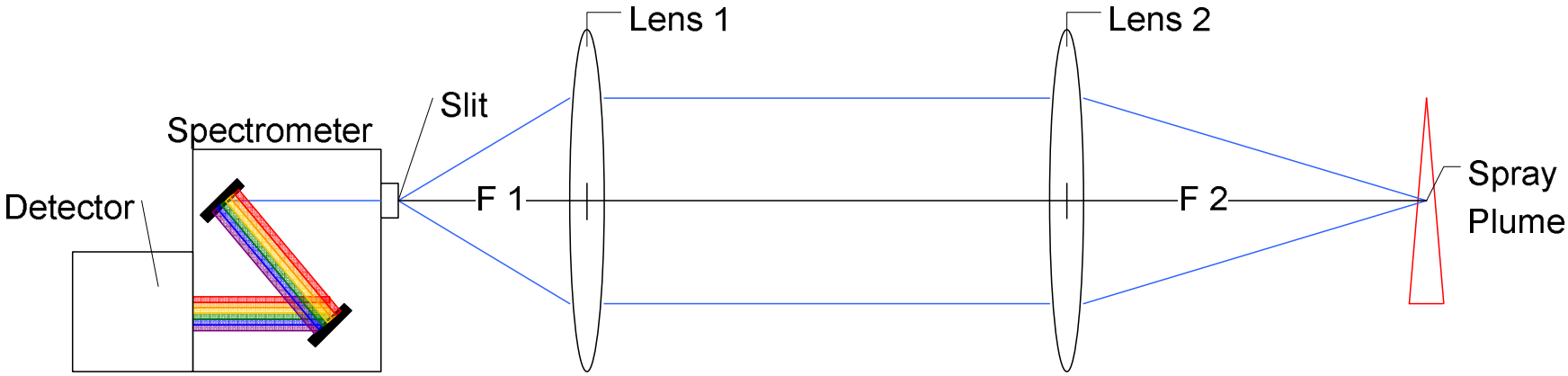
Apparatus / Calibration



- **2 lens system to image plume onto slit**
- **Calibrate diode array using tungsten lamp**
  - **Compare known radiance with actual intensity collected**

$$c'_n = \frac{\Omega A_S \tau \lambda_n L_n \Delta\lambda_n}{hcMS_n^0}$$

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Process

- Calibrate detector diode array using a source of known radiance
- Survey range of wavelengths to find appropriate range for measurement
- Use calibration curve to convert spectral intensity into number of photons
- Compare number of photons, degeneracy, transition energy, and Einstein coefficient to calculate number density

INSERT AIR PLASMA PICTURE HERE

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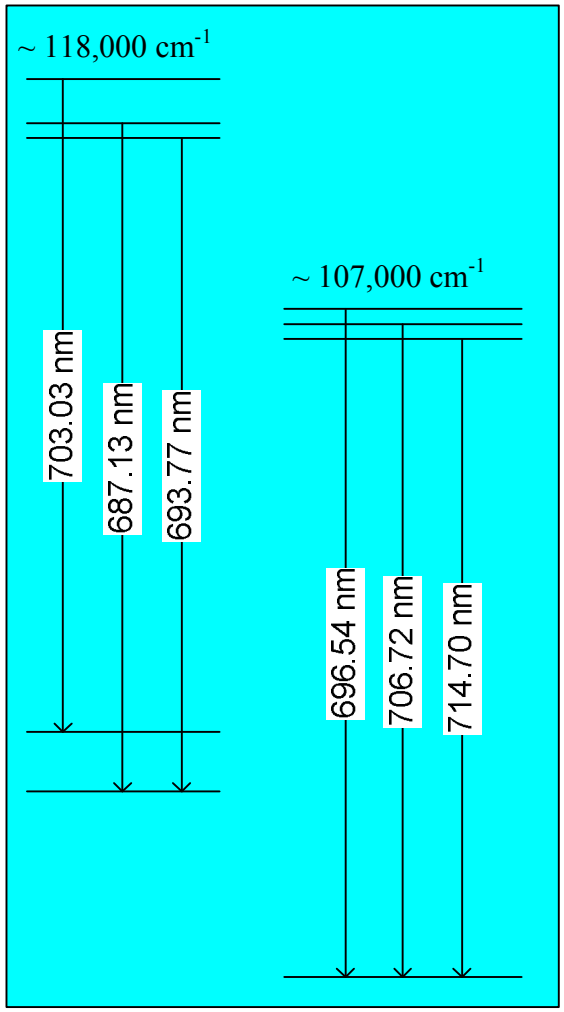
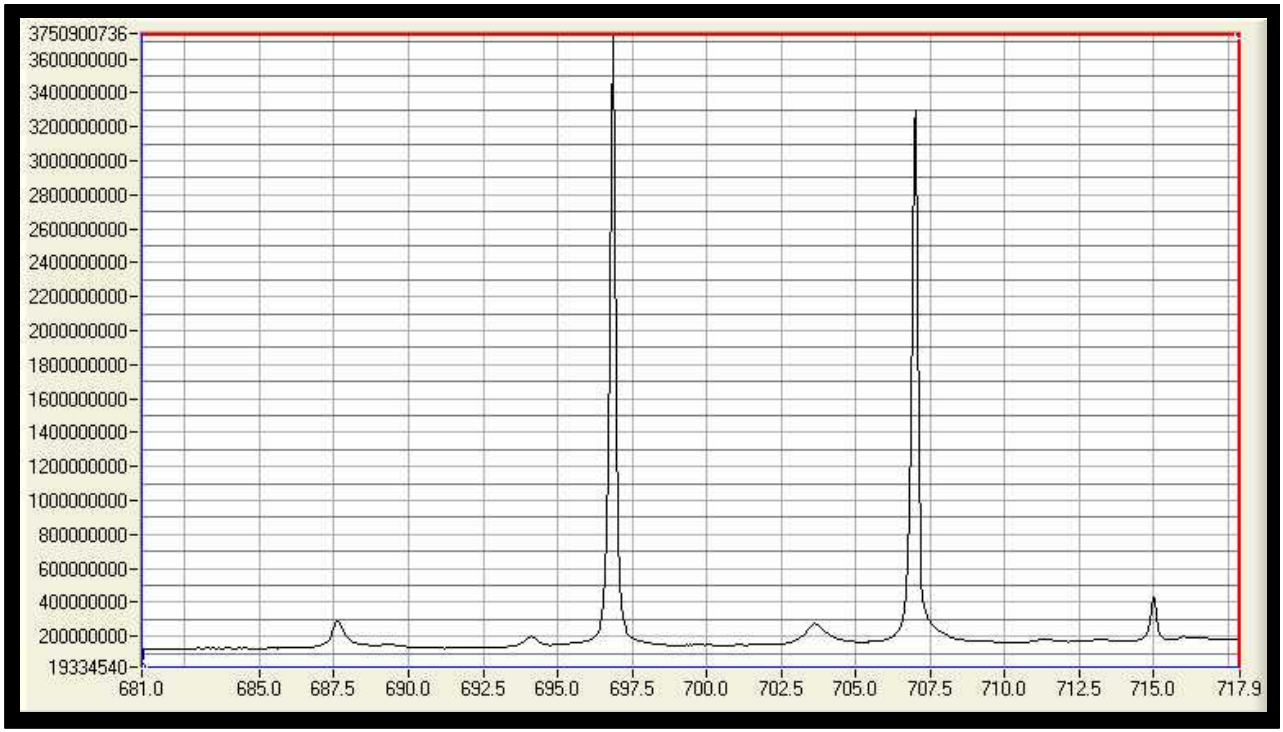
Optical Multichannel Analyzer (OMA) Data





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Average Number Density

- Detected intensity with calibration coefficients reveals number of photons for some solid angle
- Power emitted from the plume is proportional to the volume, number density, energy level and Einstein emission coefficient
- Solving for the number density

$$N_j = \frac{4\pi}{\Omega \tau V_S A_{jk}} \sum_n c'_n S_n^{jk}$$

- Assume thermodynamic equilibrium (Boltzmann distribution)

$$\frac{N_j}{g_j} = \frac{N}{Z} \exp\left(\frac{-E_j}{k_B T}\right) \qquad Z \equiv \sum_i g_i \exp\left(\frac{-E_i}{k_B T}\right)$$

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Average Temperature

- **From intensity ratios of emission lines**

$$\frac{N_j}{N_l} = \frac{A_{lm}\sum_n c'_n S_n^{jk}}{A_{jk}\sum_{n'} c'_{n'} S_{n'}^{lm}} = \frac{g_j}{g_l}\exp\left(\frac{-E_{jl}}{k_B T}\right)$$

$$T = E_{jl}\left[k_B \ln\left(\frac{g_l A_{lm}\sum_{n'} c'_{n'} S_{n'}^{lm}}{g_j A_{jk}\sum_n c'_n S_n^{jk}}\right)\right]^{-1}$$

- **From multiple emission lines**

$$\frac{N_j}{g_j} = \frac{N}{Z}\exp\left(\frac{-E_j}{k_B T}\right)$$

$$\ln\left(\frac{4\pi\sum_n c'_n S_n^{jk}}{\Omega\tau V_S g_j A_{jk}}\right) = K' - \left(\frac{1}{k_B T}\right)E_j$$

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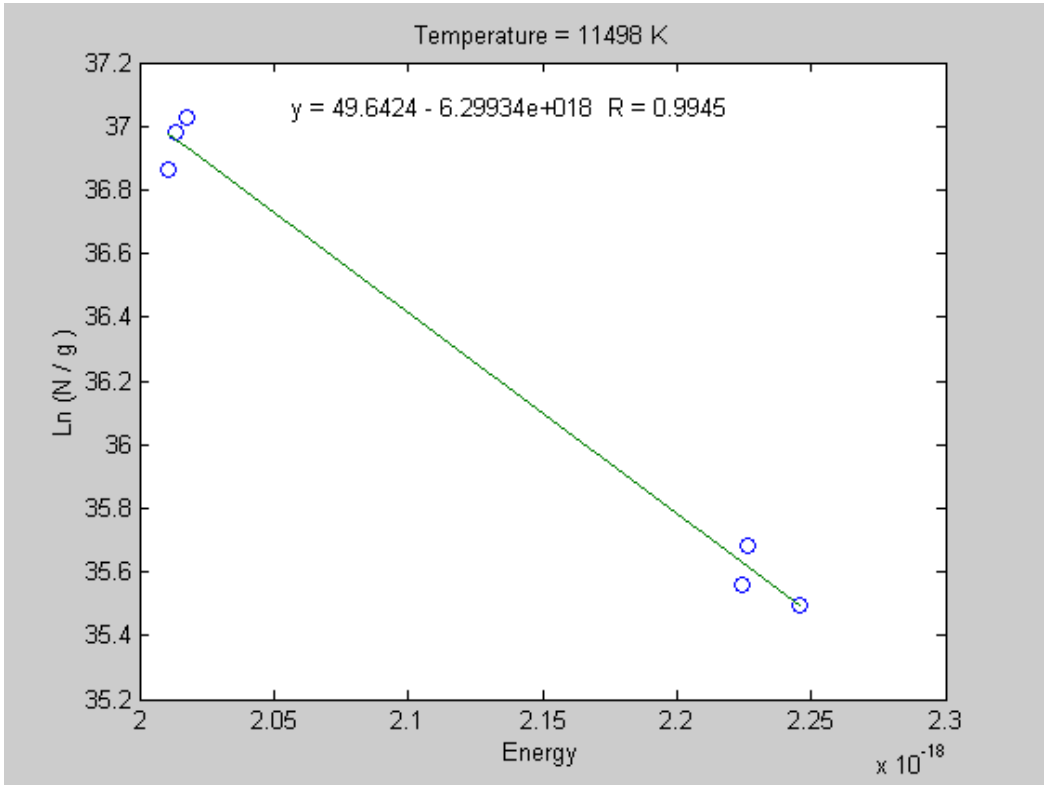

gun Voltage	Argon (SLPM)	Helium (SLPM)	Current (A)	Copper Powder	Temperature (K)
23.2	50	0	700	N	9964
23.6	50	8	700	N	10050
23.8	50	8	800	N	10310
24.9	60	8	800	N	9458
24.9	60	8	800	Y	10070
29.3	60	12	800	Y	10180

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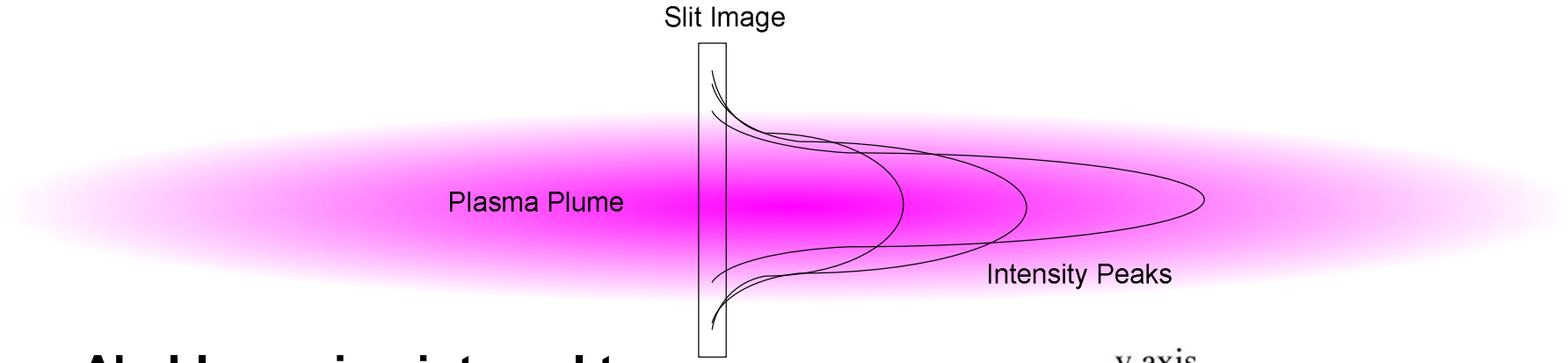
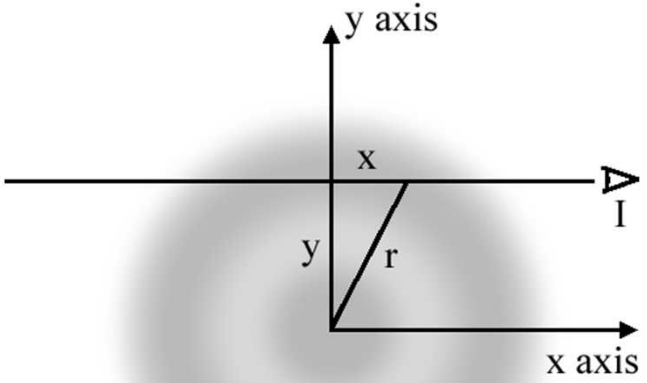
Radial Temperature Distribution



- **Abel Inversion integral to convert intensity across beam into radial distribution**



$$F(y) = 2\int_y^\infty \frac{f(r)r\,dr}{\sqrt{r^2 - y^2}}.$$

$$f(r) = -\frac{1}{\pi}\int_r^\infty \frac{dF}{dy}\frac{dy}{\sqrt{y^2 - r^2}}.$$

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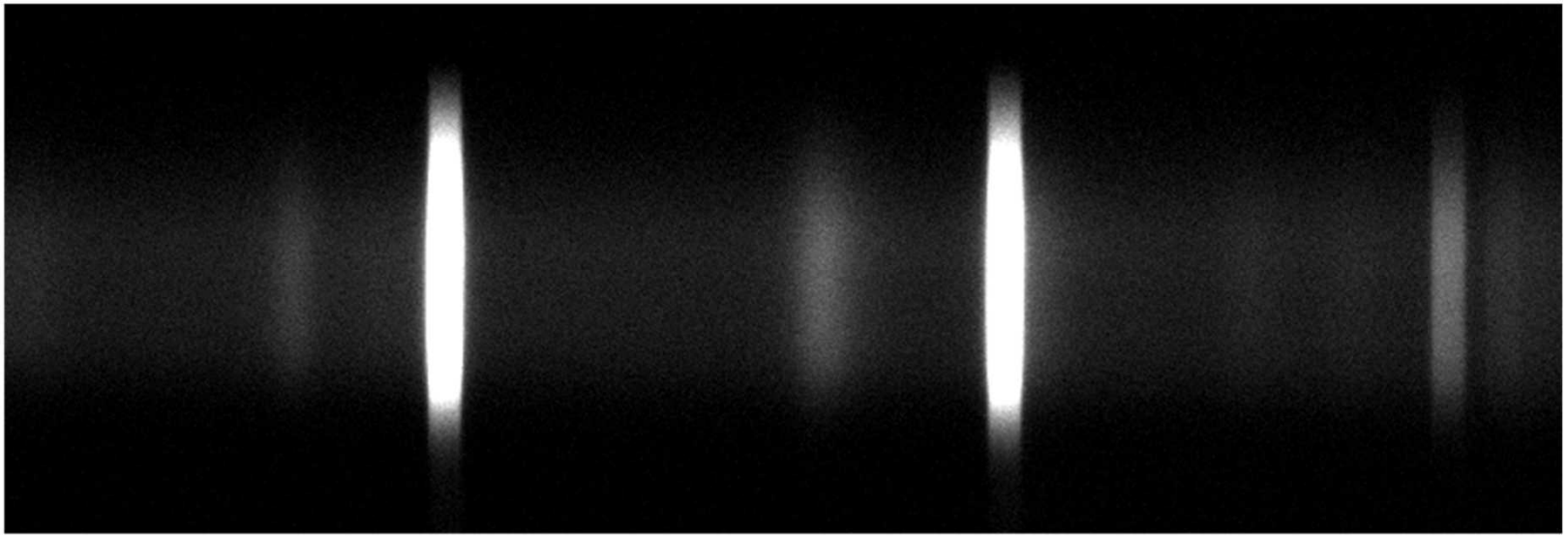

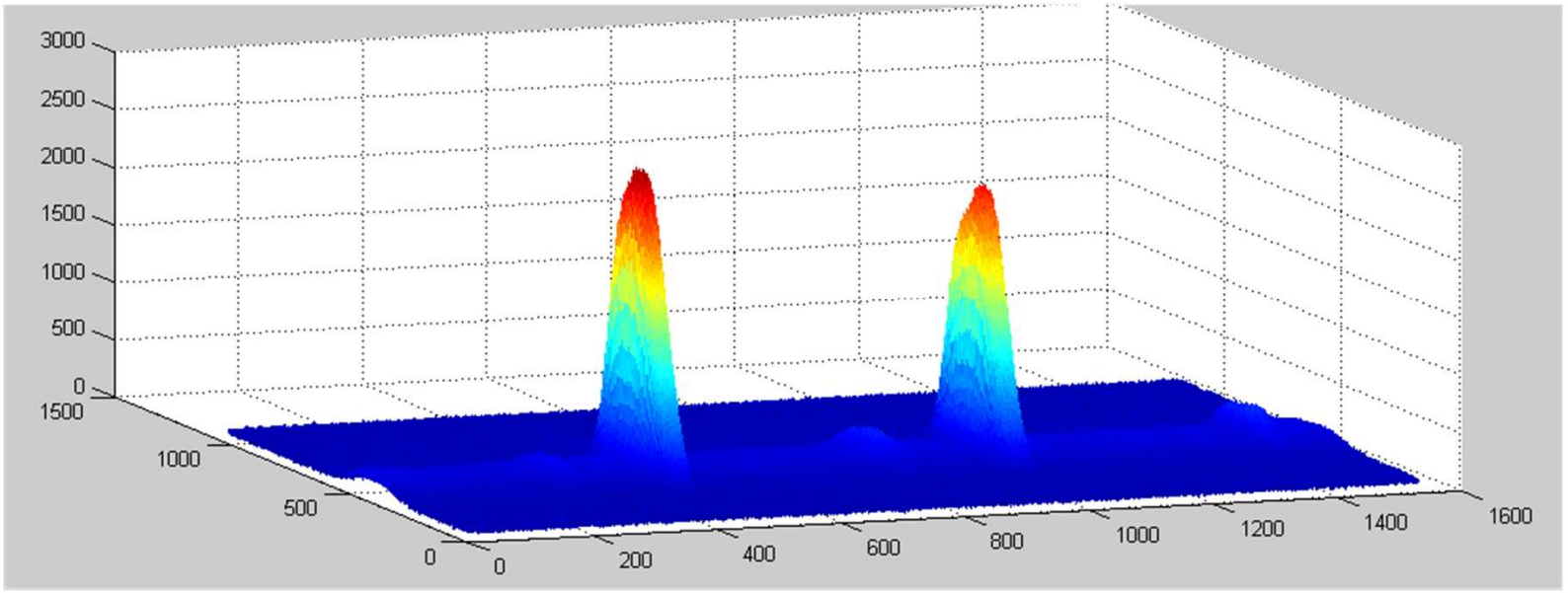

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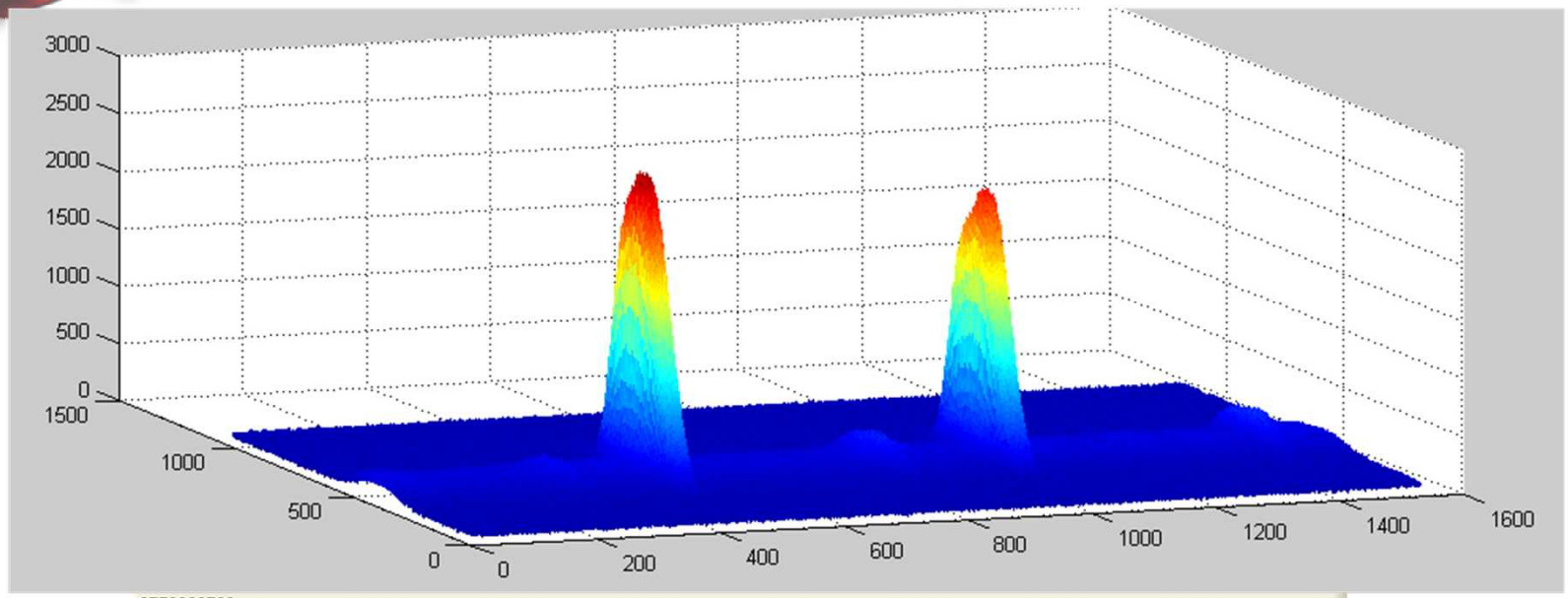

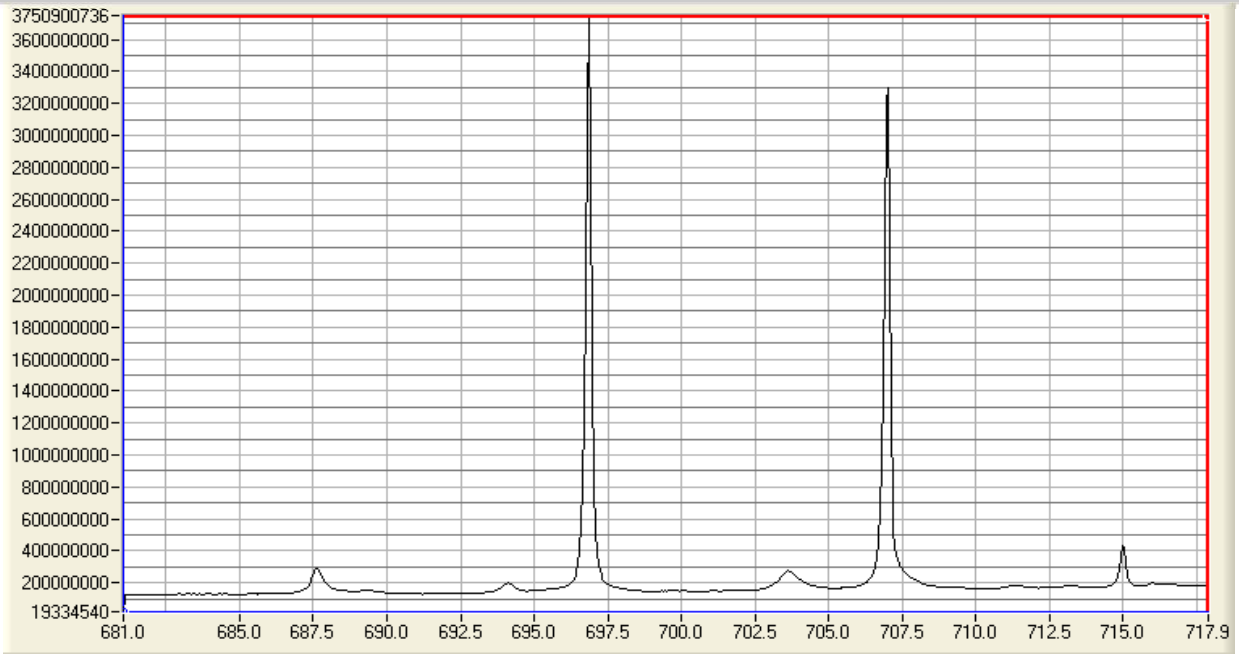

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INSERT CHART/ PICTURE
REGARDING RADIAL
TEMPERATURE DISTRIBUTION

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Future Development

- Create robust diagnostic tool that can calculate radial temperature distributions in a plasma
- Apply spectroscopic technique to Low Pressure Plasma Spray
  - Ideal for this process because many diagnostic tools are not suitable for use in vacuum chamber