[NWP.020]

Temperature measurements using selected Tm and Dy lines in Metal Halide Lamps

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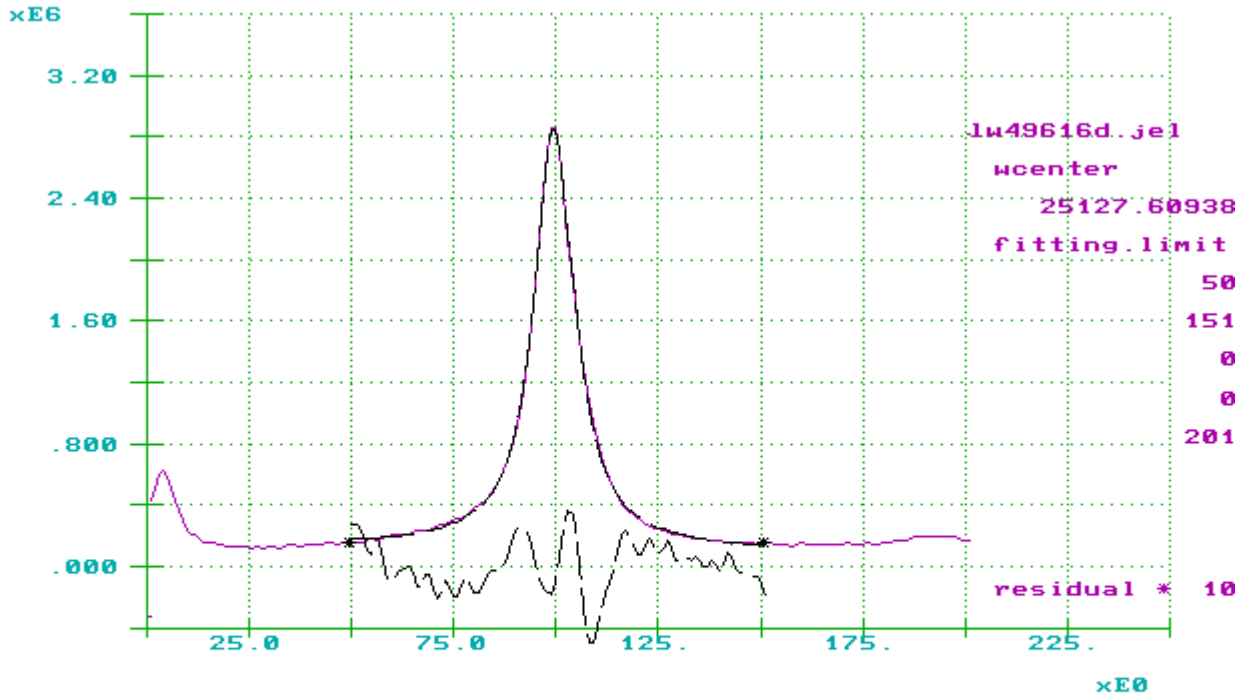
ABSTRACT

- The 1 m Fourier transform spectrometer (FTS) at the National Solar Observatory on Kitt Peak was used to record UV to IR emission spectra of Metal Halide-High Intensity Discharge (MH-HID) lamps with doses containing rare earth salts. All intrinsic structure is fully resolved in these spectra. Many additive lines were found to have nearly perfect Lorentzian profiles and to be surprisingly narrow (FWHM < 1 cm-1) [1]. Fitting these profiles to Lorentzian functions provides a sensitive test for radiation trapping and line blending [1]. We have used this fitting approach along with recently measured absolute transition probabilities [2,3] to select sets of lines in Tm I, Tm II, Dy I, and Dy II which are good for temperature determinations in MH-HID lamps. [1] H. Adler, L. Riley, amp; J. E. Lawler in Proceedings of the Ninth International Symposium on the Science and Technology of Light Sources LS:9 ed: R S Bergman (2001, Ithaca: Cornell University Press) p 129. [2] M. E. Wickliffe amp; J. E. Lawler, J. Opt. Soc. Am. B 14, 737 (1997) [3] M. E. Wickliffe, J. E. Lawler, amp; G. Nave, J. Quant. Spectrosc. Radiat. Transfer 66, 363 (2000).

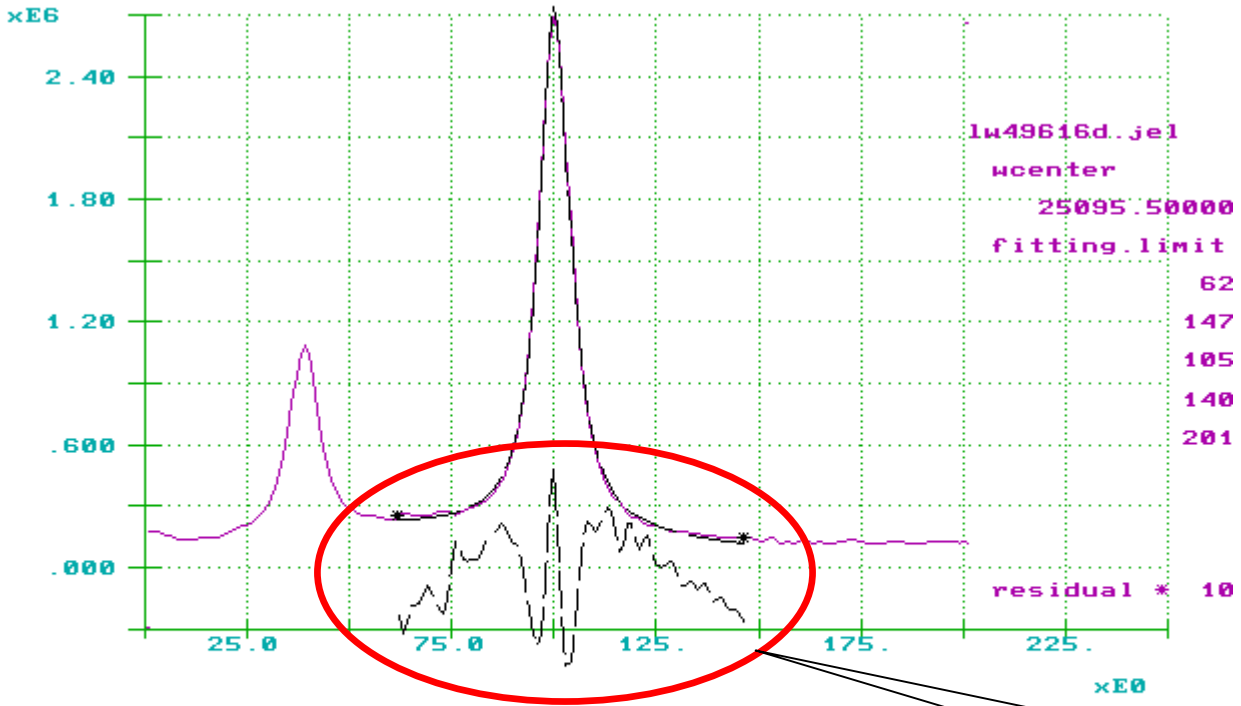
Line fitting (without self-absorption)




```
Linecenter from least square fit (cm-1)  =      25127.4633
Line width from fit, FWHM (cm-1)         =          .6767
Line intensity from fit, above baseline  =    2920596.7500
Baseline intensity at left edge of plot  =     155070.4375
Baseline intensity at right edge of plot =      84564.6016
OK _
```

Line fitting (self-absorption)

If we ignore the self- absorption, fitting will be w-shape (bad).

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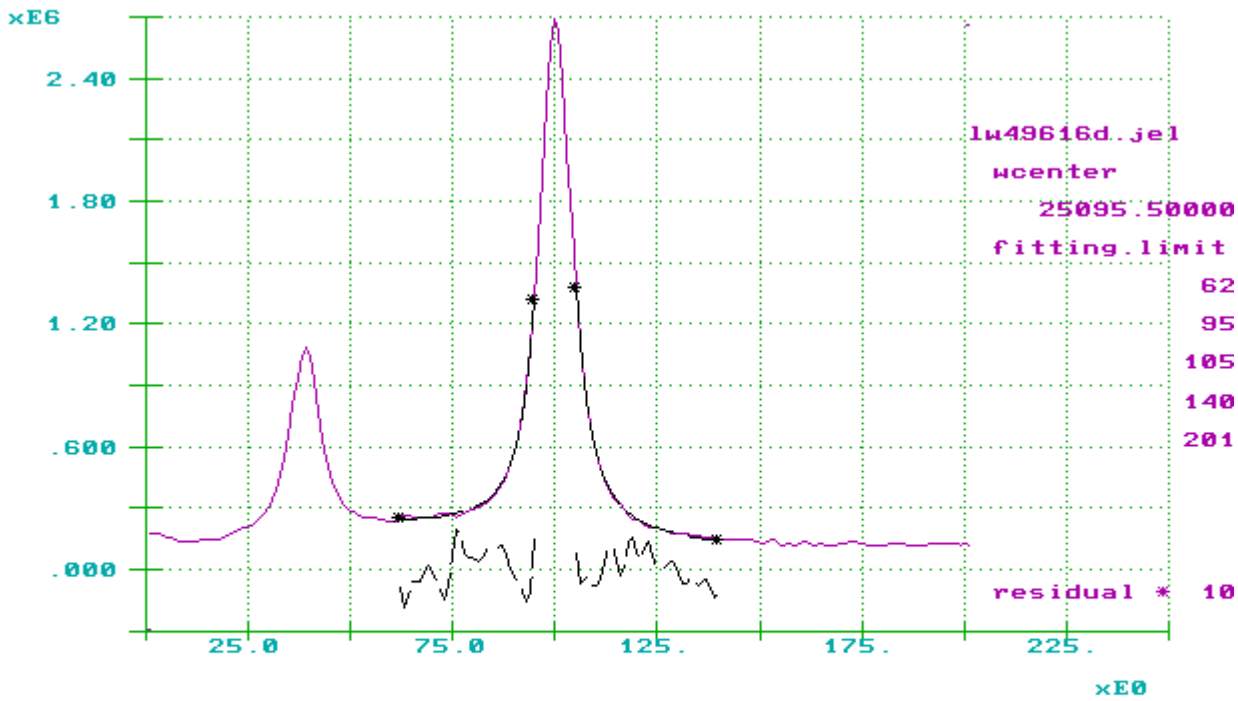
Linecenter from least square fit (cm-1)   =      25095.3941
Line width from fit, FWHM (cm-1)          =          .5182
Line intensity from fit, above baseline   =    2108420.0000
Baseline intensity at left edge of plot   =     270428.1563
Baseline intensity at right edge of plot  =      26081.4766
OK _
```

W-shape
(Bad fitting)

Line fitting (self-absorption)

We solve the self-absorption problem to divide two fitting area.

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Linecenter from least square fit (cm-1)  =      25095.3915
Line width from fit, FWHM (cm-1)         =          .4219
Line intensity from fit, above baseline  =    2250212.0000
Baseline intensity at left edge of plot  =     297439.0000
Baseline intensity at right edge of plot =      25143.2930
OK _
```
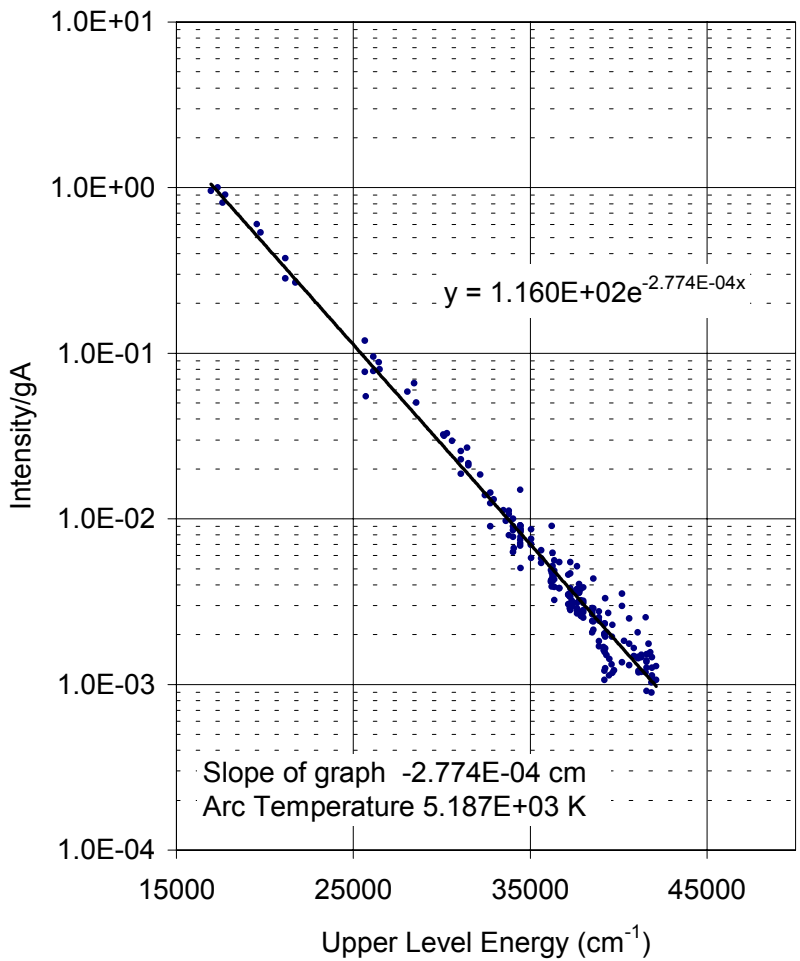
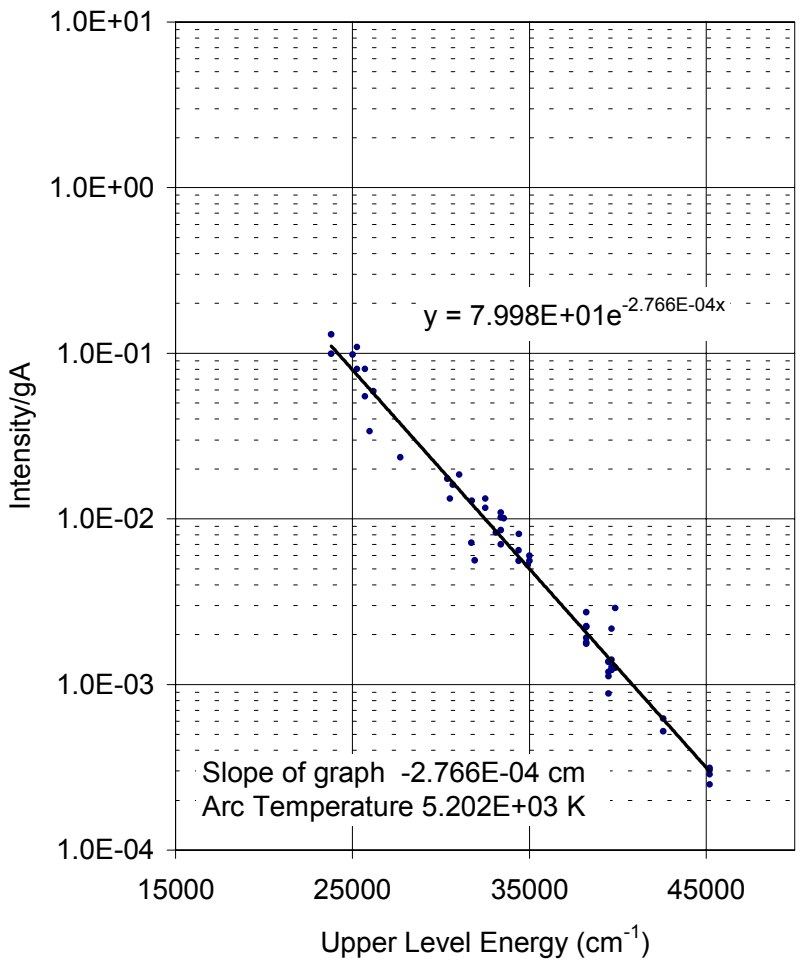

Boltzmann plot

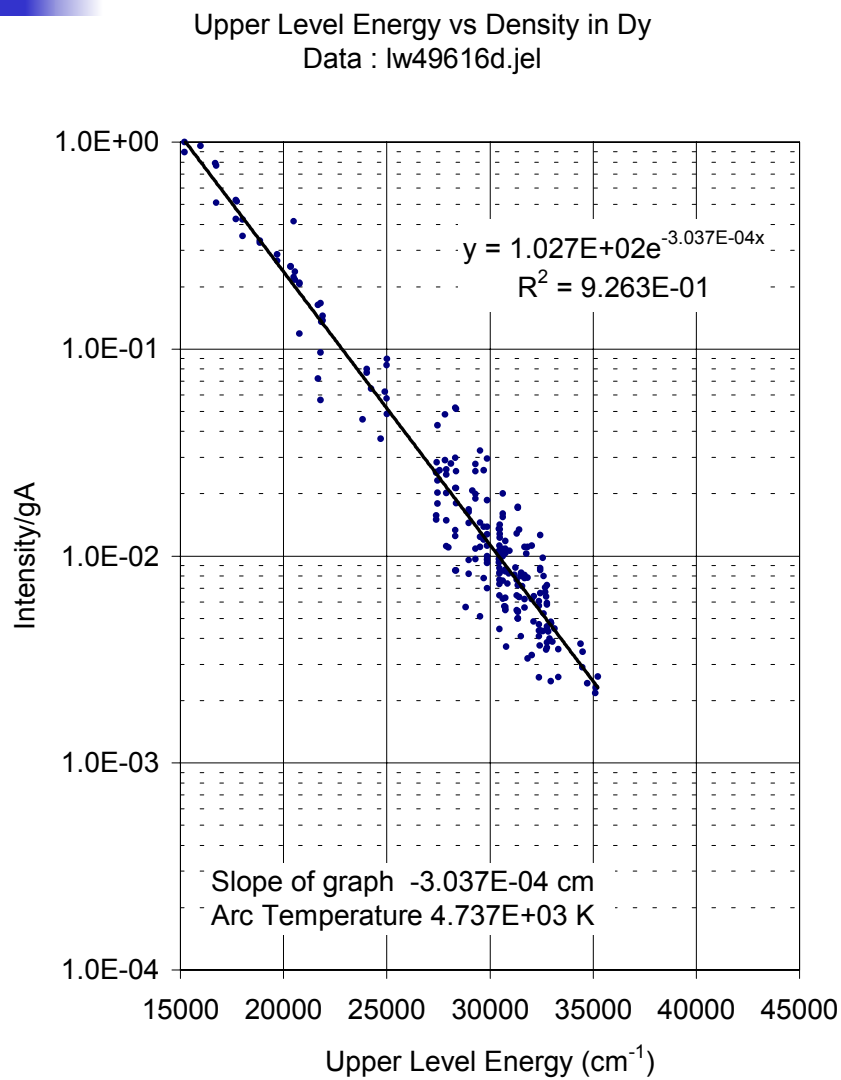
- Assume LTE (Local thermodynamic equilibrium)
- Relative population $\propto g_u e^{-E/k_B T}$
  - g_u : Degeneracy
  - k_B : Boltzmann constant
  - T : Temperature
  - E : Energy in upper level
- $$\log \frac{I_{ul}}{A_{ul} g_u} = -\frac{1}{k_B T} E_{ul} + const.$$

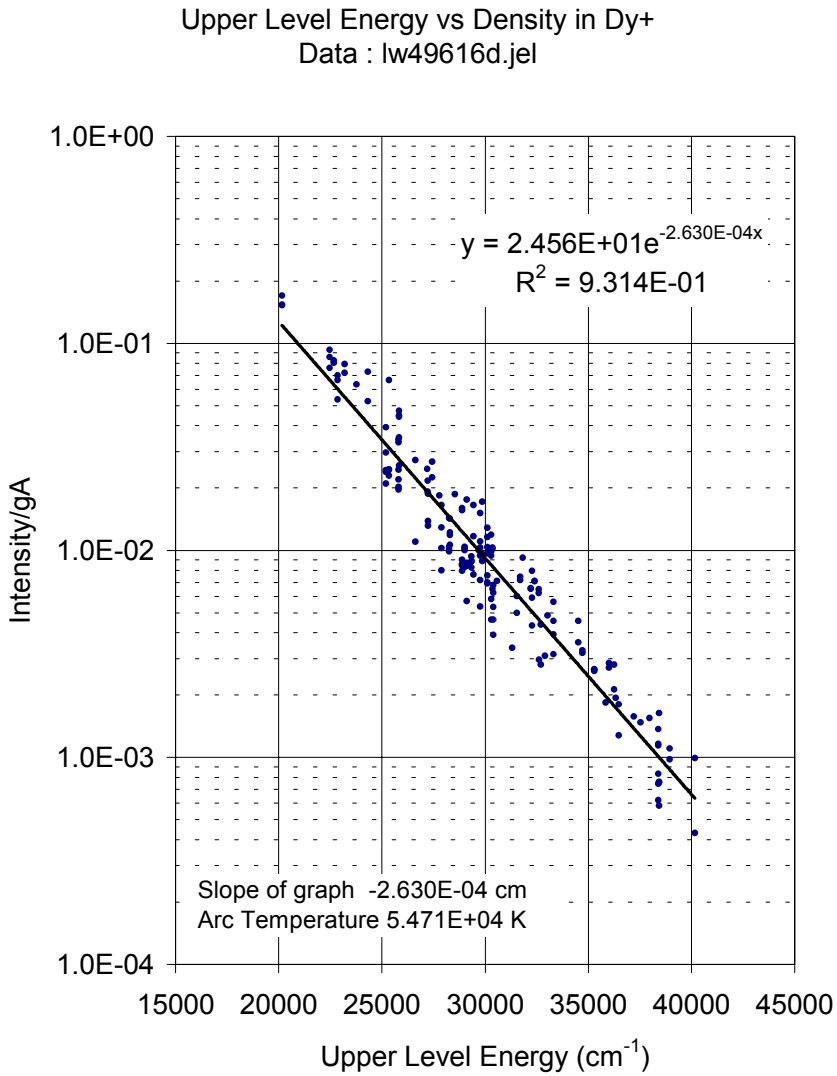
Boltzmann plot of Tm, Tm+





Boltzmann plot of Dy, Dy+





Results of temperature cal.

	Temperature
Tm	5187 [K]
Tm+	5202 [K]
Dy	4737 [K]
Dy+	5471 [K]

Saha Equation

$$K_I(T) = \frac{[n_e][Tm^+]}{[Tm]}$$

$$I_{Tm} = gAe^{-E_{ul}/kT}[Tm]/4\pi \quad Z_{Tm}$$

$$I_{Tm^+} = gAe^{-E_{ul}/kT}[Tm^+]/4\pi \quad Z_{Tm^+}$$

Z_{Tm} : *partition function for Tm*

Z_{Tm^+} : *partition function for* Tm^+

$$\frac{[Tm^+]}{[Tm]} = \frac{\left(\frac{I_{Tm^+}}{gA} Z_{Tm^+}\right)}{\left(\frac{I_{Tm}}{gA} Z_{Tm}\right)}$$

Tm lamp

E_{ul}= 35000

	Intensity/gA	Temperature [K]	Partition function Z
Tm	7.045E-03	5187	11.0068
Tm+	4.995E-03	5202	18.1768

Average Temparature (Tavg)	5194.5 [K]
Equilibrium const. $K_I(T_{avg})$	2.874E+15 [cm^{-3}]
electron density (n_e)	2.455E+15 [cm^{-3}]

Dy lamp

E_{ul}= 30000

	Intensity/gA	Temperature [K]	Partition function Z
Dy	1.134E-02	4737	42.6232
Dy+	9.197E-03	5471	55.7244

Average Temparature (Tavg)	5104 [K]
Equilibrium const. $K_I(T_{avg})$	3.152E+15 [cm^{-3}]
electron density (n_e)	2.973E+15 [cm^{-3}]

Conclusion

- By fitting of spectral line profiles, the best lines for arc temperature measurements are identified.
- Ion excitation temperature is apparently higher than neutral atom excitation temperature due to the higher concentration of ions on axis.
- Electron density can be determined using the Saha equation.

Future Work

- The identification of "good" (strong, unblended, optically thin) lines of Tm, Tm^+, Dy, Dy^+ will enable us to use a small subset of lines in limited wavelength range to determine accurate values for T(r) and $n_e(r)$ from a Abel inversion of emission spectra along chords through the arc.