Temperatures of Atmospheric MSRR-MIP Discharges by OES Method

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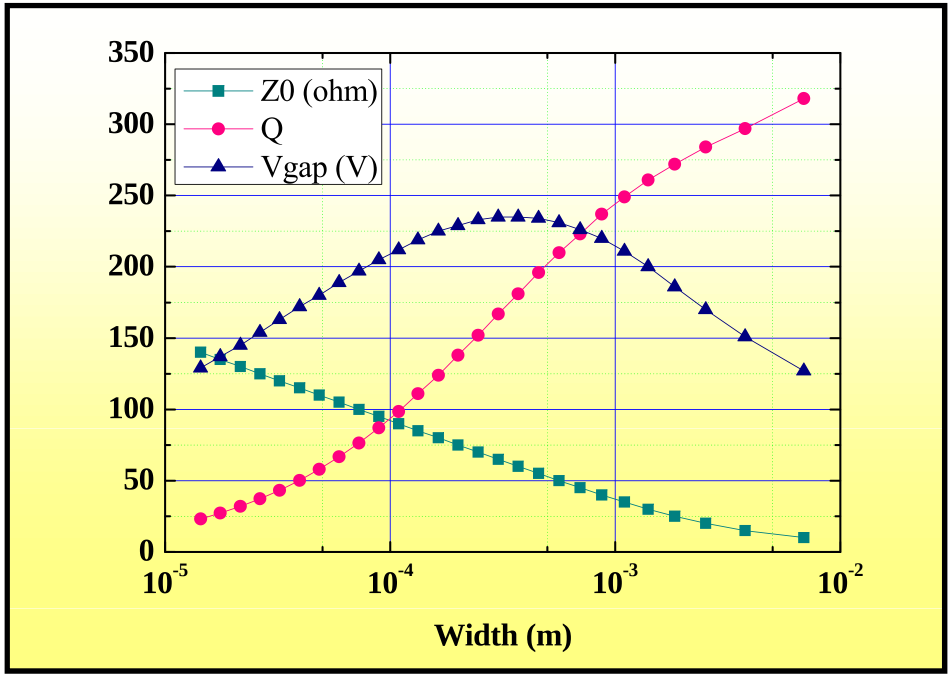
Abstract

Microwave induced atmospheric micro-plasma sources can be used for portable plasma systems. Gas temperature of Micro-strip Split Ring Resonator Microwave Induced Plasma (MSRR-MIP) was obtained by the Optical Emission Spectroscopy (OES) measurement in comparison with the synthetic spectra of OH. In addition, this experiment describes excitation, and also electron temperatures of MSRR-MIP. Atmospheric Argon discharges are operated with 2.45 GHz, 1.2 W microwaves. In this paper, we present design of the MSRR-MIP device and operational characteristics in detail.

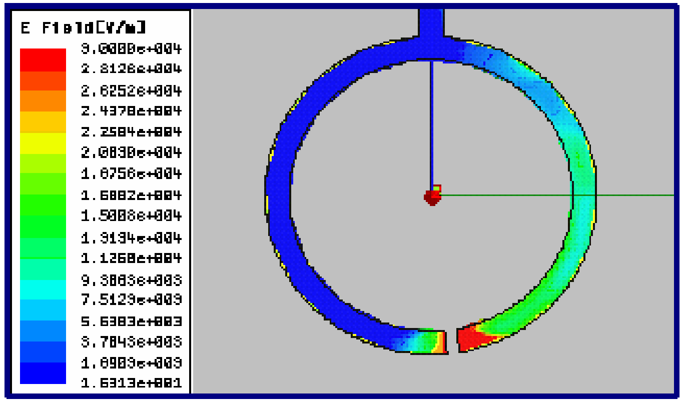
Contents

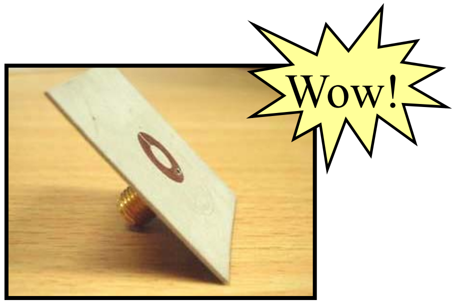
Design of the MSRR-MIP

1. Calculation

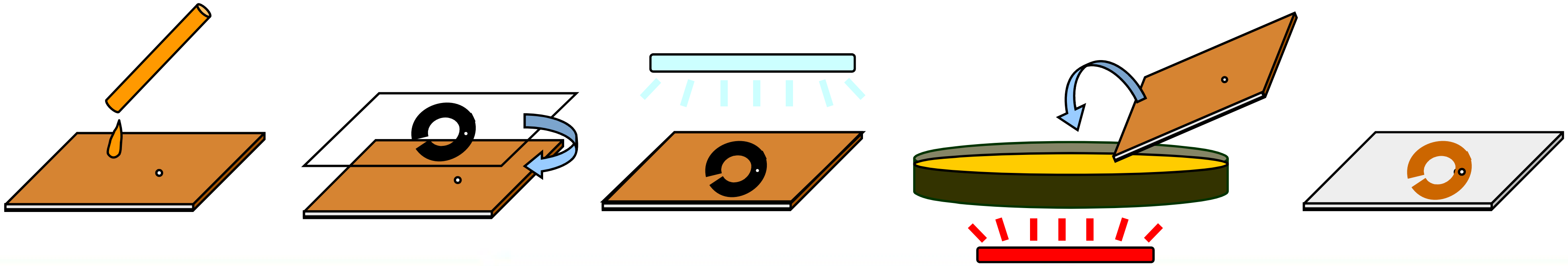


2. Simulation

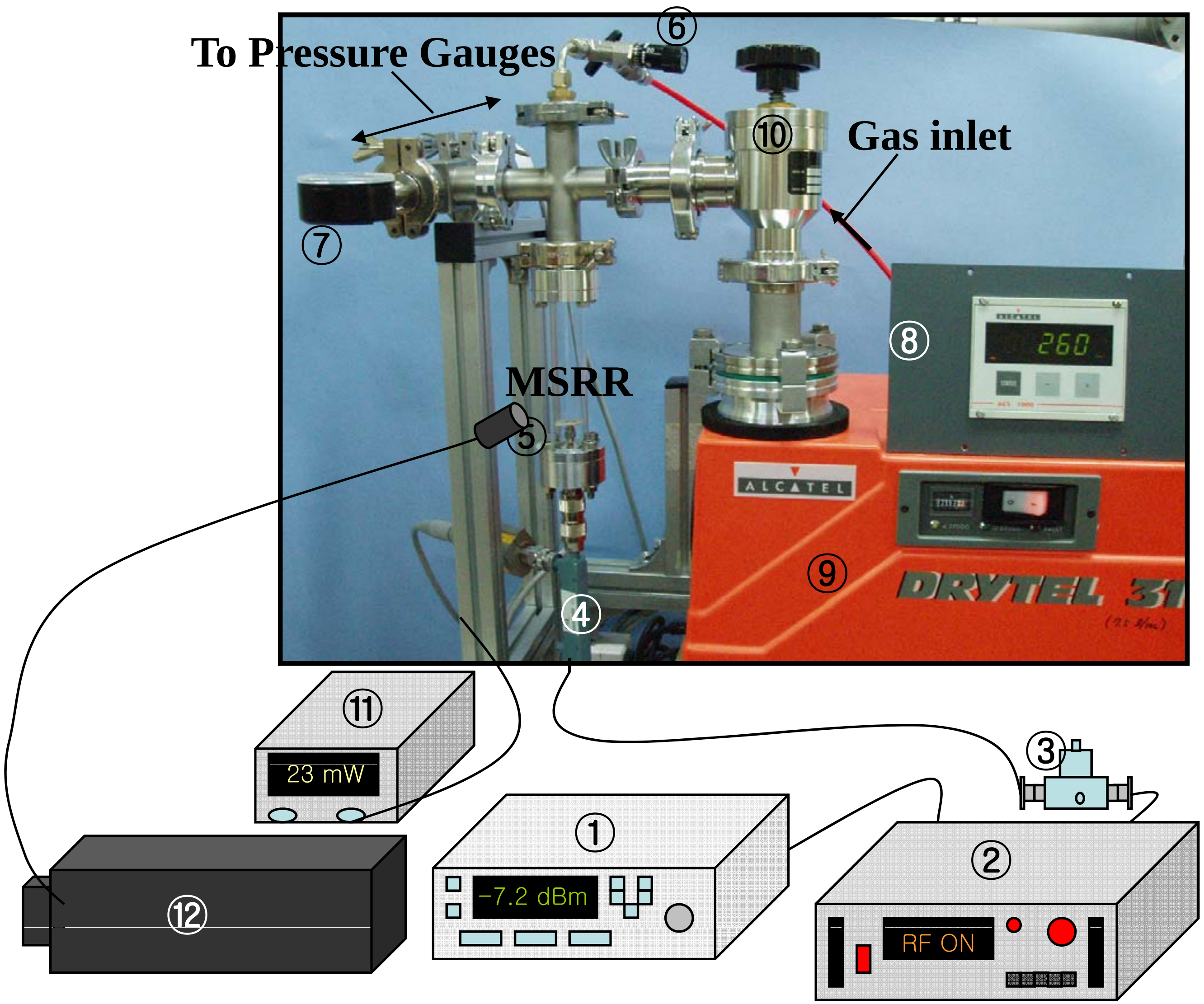




3. Fabrication



Experimental Setup



① Swept signal generator
② Amplifier
③ Isolator
④ Directional coupler
⑤ MSRR
⑥ Needle valve
⑦ Pressure gauge
⑧ Pressure gauge
⑨ Vacuum pump
⑩ Angled valve
⑪ Power meter
⑫ Spectrometer

Boltzmann Plot Method

- **Population of atomic excited states assuming that this follow a Boltzmann distribution.**

$$I_{ul} \propto h\nu_{ul} A_{ul} n_{ul} \propto \frac{h}{\lambda_{ul}} A_{ul} g_{ul} \exp\left(-\frac{E_u}{kT_{exc}}\right)$$

where, h : Planck's constant

ν_{ul} : the frequency of the emitted photon

λ_{ul} : the wavelength of the emitted photon

A_{ul} : the Einstein coefficient

n_u : the density of atoms in the excited state u

- **Slop: -1.4388 / T_{exc} (E in eV), -11632.08 / T_{exc} (E in K)**

Synthetic Spectrum

◆ **Theoretically, the intensity of rotational spectrum of diatomic molecular species is,**

$$I_0 = D_0 k^4 S \exp(-\frac{E_r}{k_B T_{rot}})$$

◆ **OH rotational spectrum at 3000 K, *I** has been known by Dieke and Crosswhite. The spectrum of arbitrary temperature, I_0 can be obtained through *I** .**

$$I_0 = I_0^* \exp(-\frac{E_n(3000-T)}{3000T})\frac{Q(T^*)}{Q(T)}$$

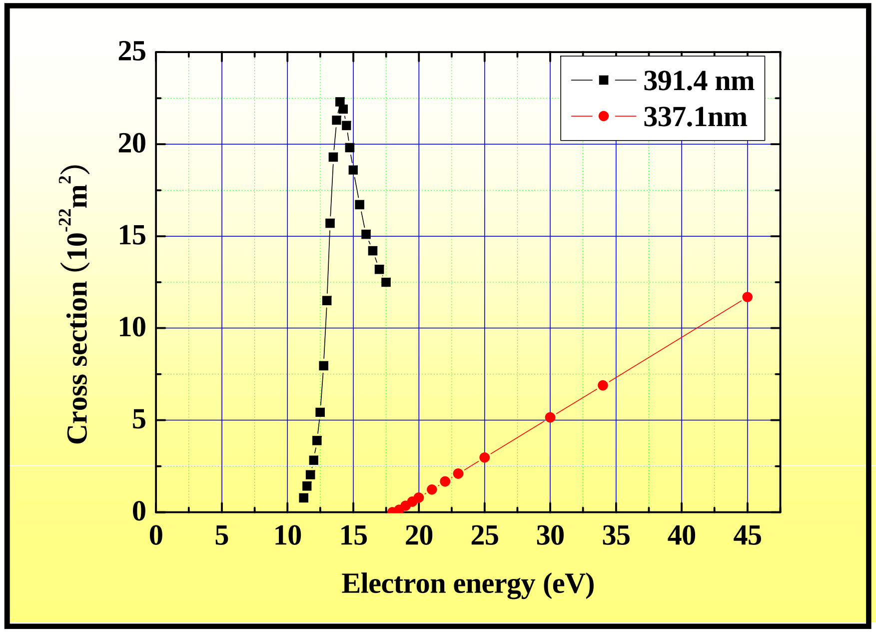
◆ **The spectrum of considered line broadening effect is as follow.**

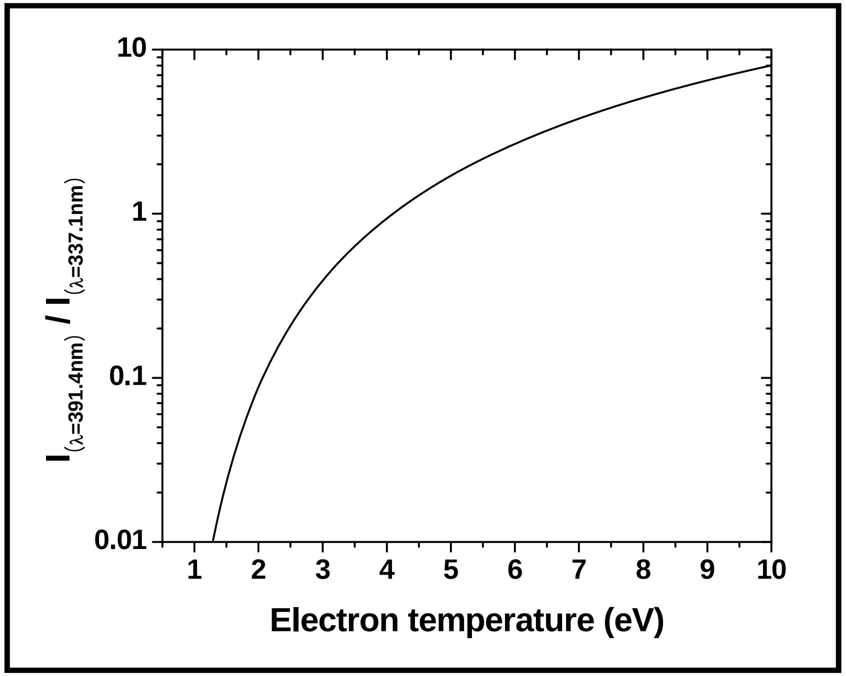
$$I = \frac{I_0}{\Delta_i \sqrt{\pi/2}} \exp(-\frac{2(\lambda-\lambda_0)^2}{\Delta_i^2})$$

where Δ_i is the FWHM of the Gaussian-shaped instrumental broadening.

◆ **The synthetic spectrum is obtainable to add each spectrum, *I*.**

Line Pair Intensity Ratio Method





$$\frac{I_{ij}^{Obs}}{I_{ab}^{Obs}} = \frac{b_{ij} T_e^{-3/2} \int_0^\infty \sigma_i^{App}(E) \exp\left[-E / kT_e\right] E dE}{b_{ab} T_e^{-3/2} \int_0^\infty \sigma_a^{App}(E) \exp\left[-E / kT_e\right] E dE}$$

where,

I_{ij} : Emission intensity

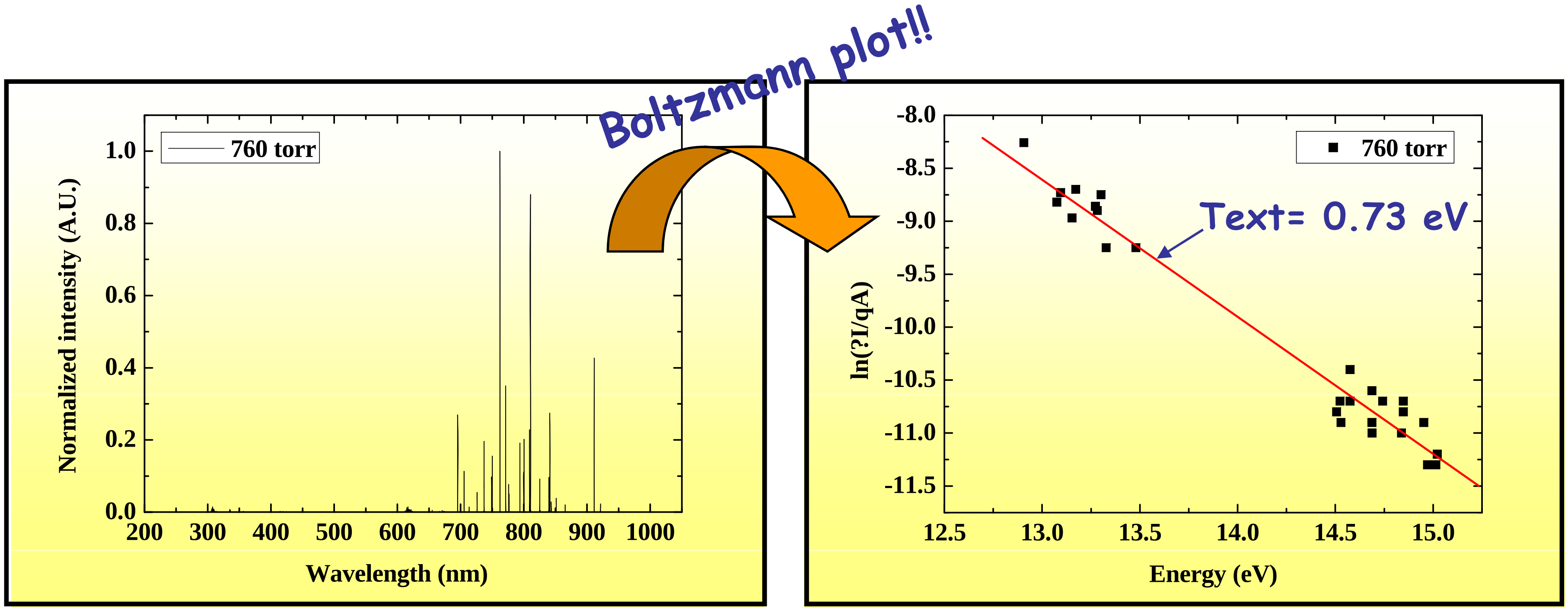
σ^{App}_{ij} : Apparent cross section

b_{ii} : branch ratio

k : Boltzmann constant

T_e : electron temperature

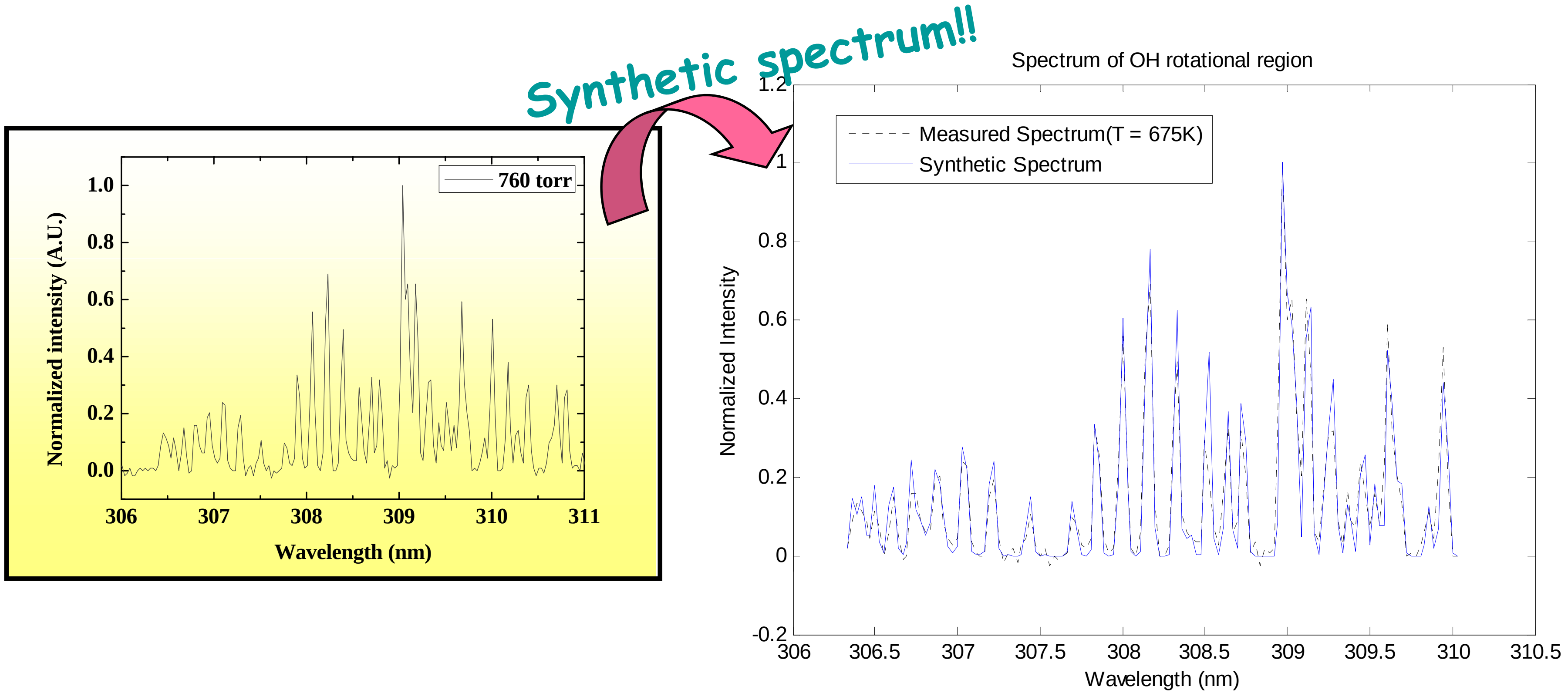
Excitation Temperature



◆ **Boltzmann plot for the determination of the excitation temperature for an argon discharge at atmospheric pressure.**

◆ **The excitation temperature is 0.73 eV= 8468 K.**

Rotational Temperature

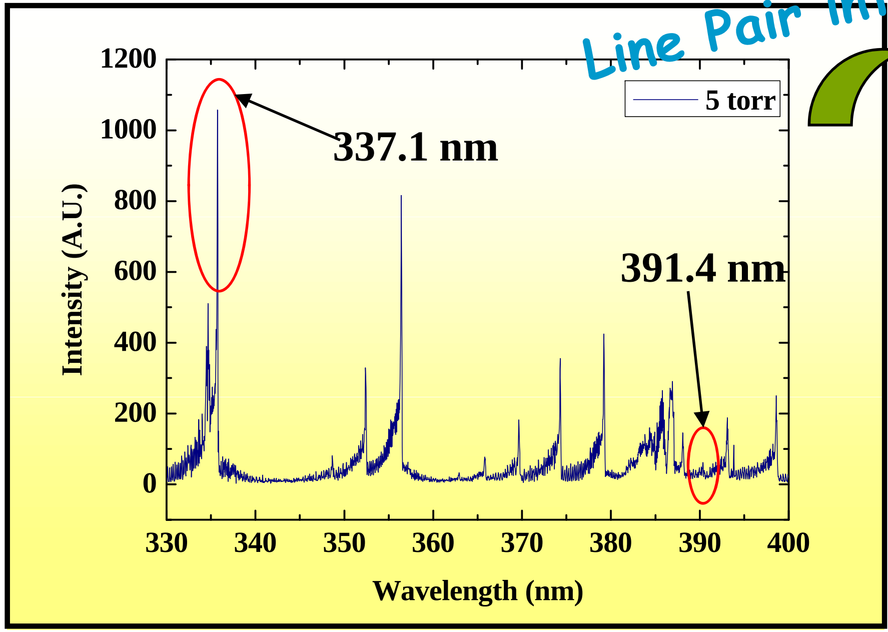


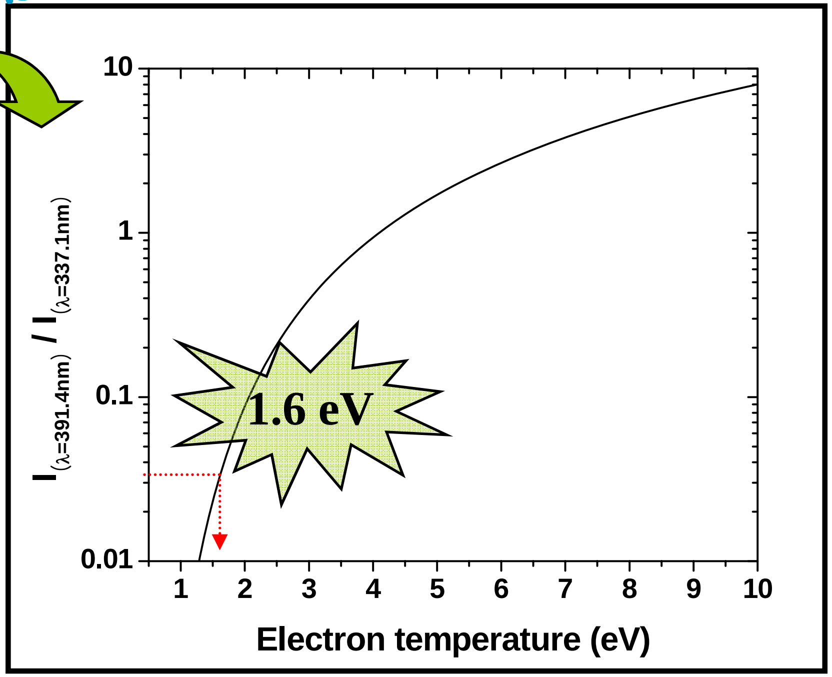
◆ **The normalized rotational spectrum of OH molecule is measured at atmospheric pressure.**

◆ **The rotational temperature is 675 K.**

Electron Temperature

Line Pair intensity ratio method!!





- The spectrum of nitrogen molecule is measured at 5 torr.
- The electron temperature is calculated by Line Pair Intensity Ratio Method.
- The electron temperature is 1.6 eV=18560 K.

Conclusion and Future Work

1. Conclusion

- **The excitation, rotational and electron temperature of an argon discharge have been studied for a variety of pressure and power conditions by Optical Emission Spectroscopy (OES).**
- **The excitation temperature of an atm plasma found by Boltzmann plot method is about 8500 K.**
- **Based on the results obtained by Synthetic spectrum method, the rotational temperature of an atm microwave discharge plasma is 675 K.**
- **The electron temperature, measured by Line pair intensity ratio method, is 18560 K at 5 torr.**

2. Future Work

- **Study the MIP characteristic with measured temperature.**
- **Measuring of electron density using Cut-off probe.**
- **Study the diagnostic method for electron density and the theoretical model .**