

Measurement of extreme ultraviolet (EUV) intensity  
of coaxial focused plasma  
in accordance with the pressure of Argon and Ne-Xe(30%)  
for EUV light source

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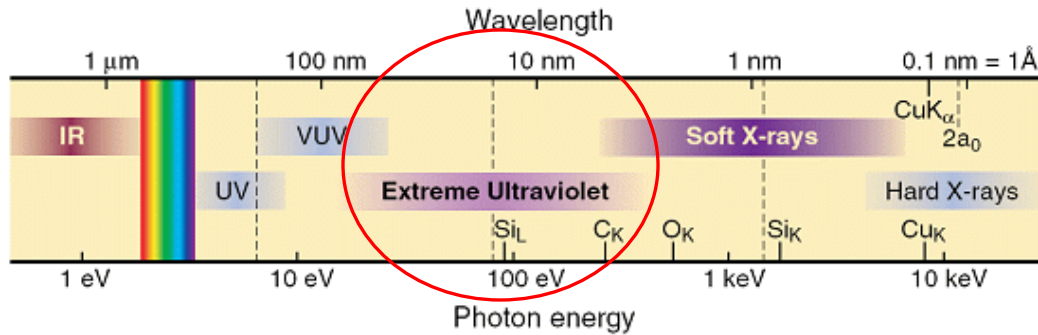
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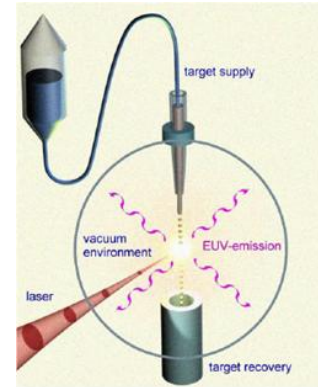
# Procedure

- Introduction
- Experimental setup
- EUV emission measurement
- Electron temperature measurement using Boltzmann plot
- Conclusion & Future work

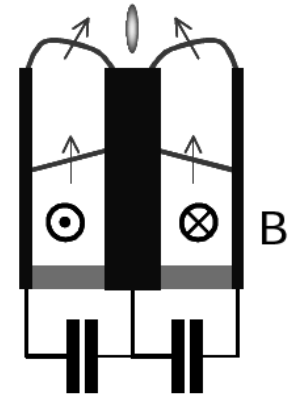
# Introduction



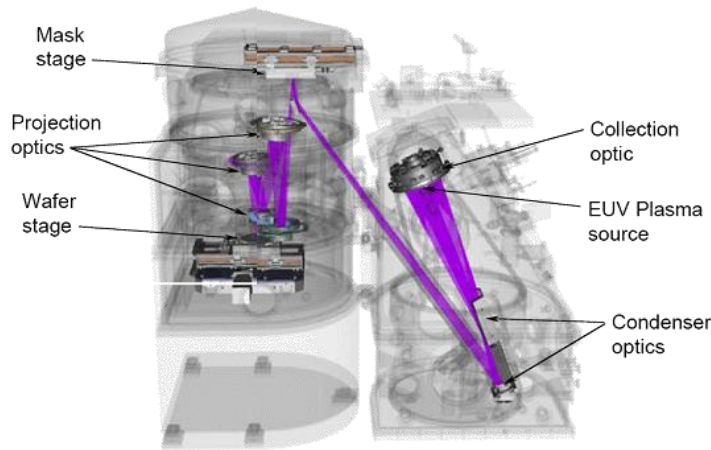
< Extreme Ultraviolet wavelength >



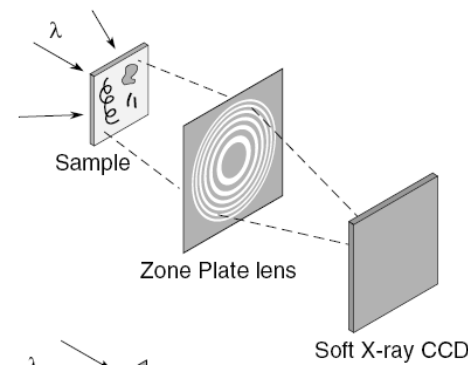
< Laser produced Plasma >



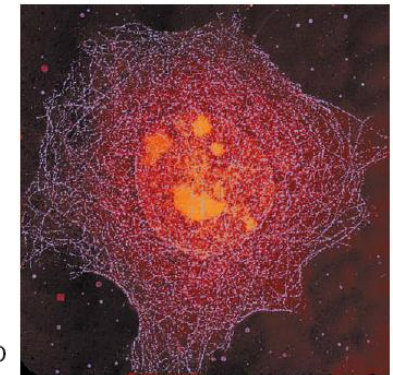
< Gas Discharge Produced Plasma >



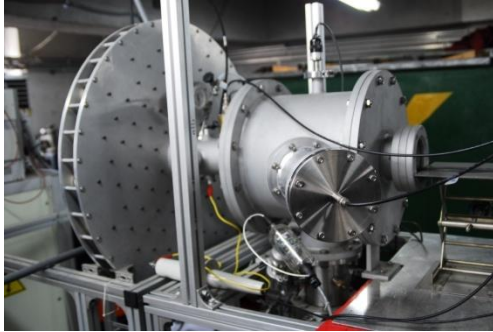
< Extreme ultraviolet lithography (EUVL) for printing circuits at the 32 nm node >



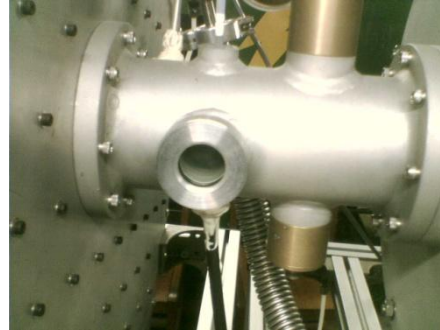
< Protein image of Soft x-ray microscope >



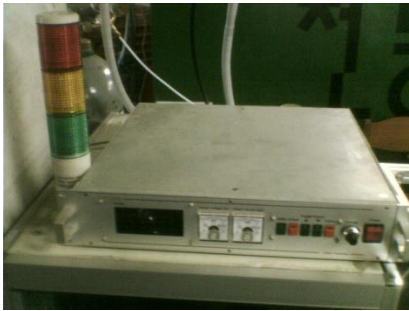
# Schematic of Plasma focus device



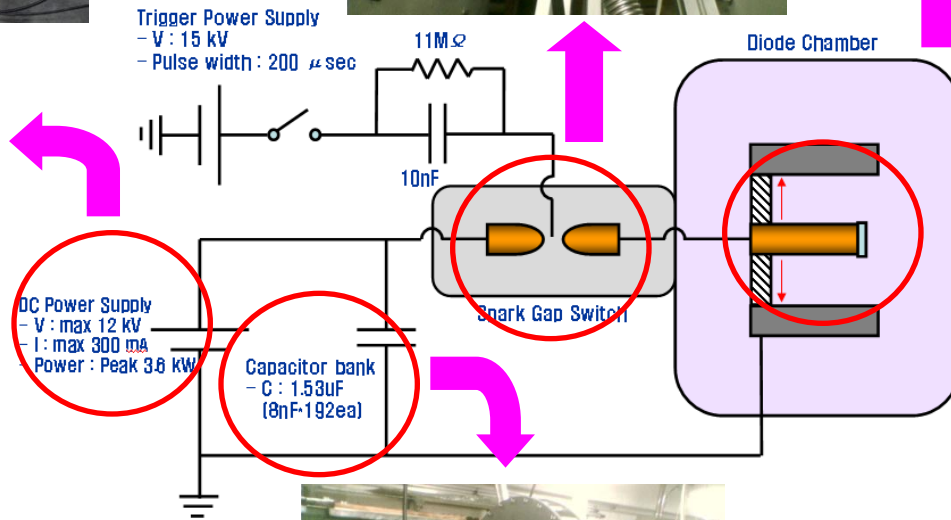
<EUV generator>



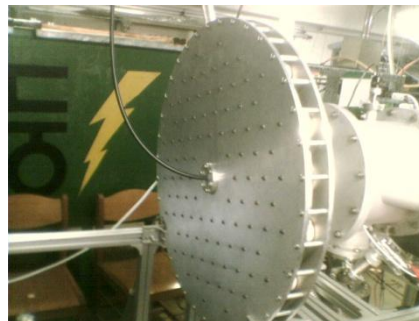
<Spark gap switch chamber>



<Power supply controller>

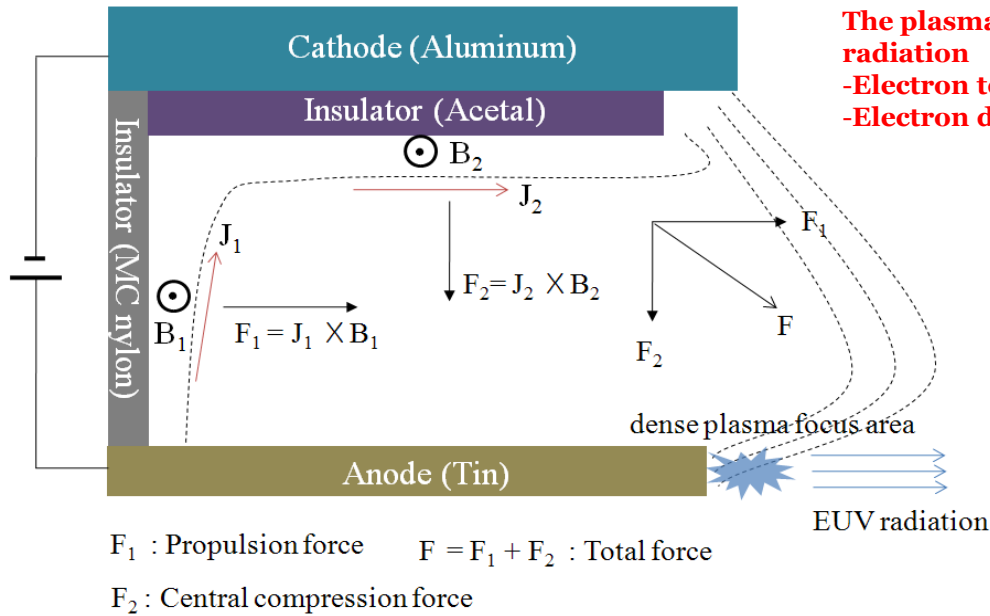


<Diode chamber>

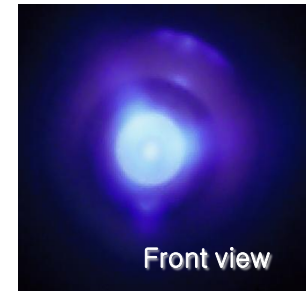
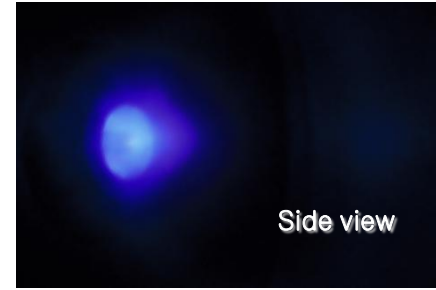


<Capacitor bank>

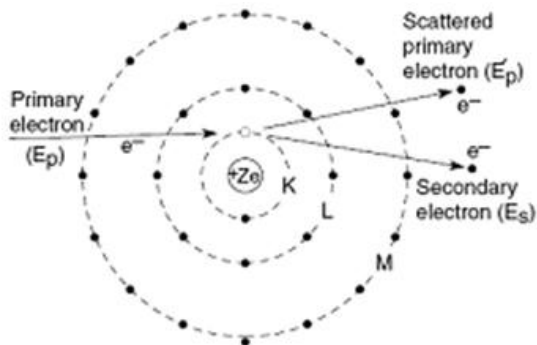
# The concept of Plasma focus



<discharge image>



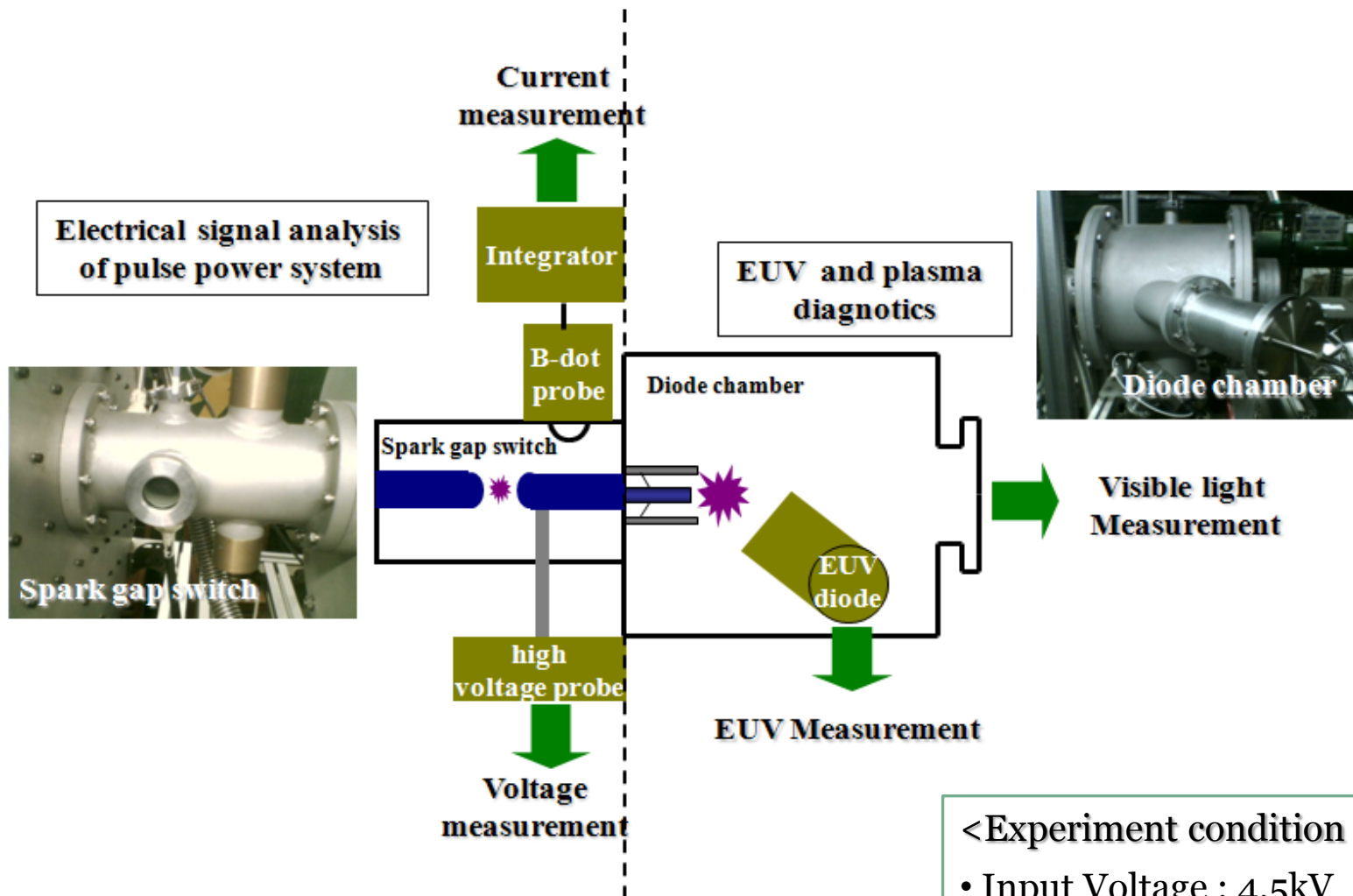
The current density  $J_1$  and  $J_2$  flow through plasma sheath of insulator surface and generate the magnetic field around current. Then  $J \times B$  Lorentz force accelerates the plasma away from insulator surface. Propulsion force  $F_1$  push the plasma ahead MC nylon insulator and central compression force  $F_2$  push the plasma into central axis of anode. These plasma is focused toward the anode tip by total force  $F(=F_1+F_2)$ . The EUV light was emitted by this dense plasma focus area. The optimum plasma parameter for EUV radiation have the electron temperature of 20 to 30 eV and the electron density  $10^{16}$  to  $10^{18} \text{ cm}^{-3}$ .



An incident primary electron of sufficiently high energy  $E_p$  is scattered by an atom as it knocks free a core electron from the K-shell. The primary electron now travels in a new direction, with a reduced energy  $E'_p$ . The lost energy is used to overcome the binding energy of the previously bound electron, and to impart kinetic energy to what is now referred to as a secondary electron. The core vacancy can then be filled by a higher-lying L or M shell electron.

## The concept of EUV radiation

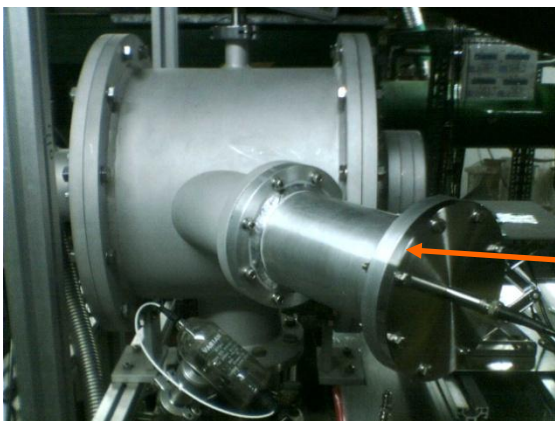
# Experimental setup



## <Experiment condition >

- Input Voltage : 4.5kV
- Gas : Ne-Xe (30%), Ar
- Repetition rate : Single pulse
- Gas Pressure range : 1~130mTorr

# EUV signal measurement

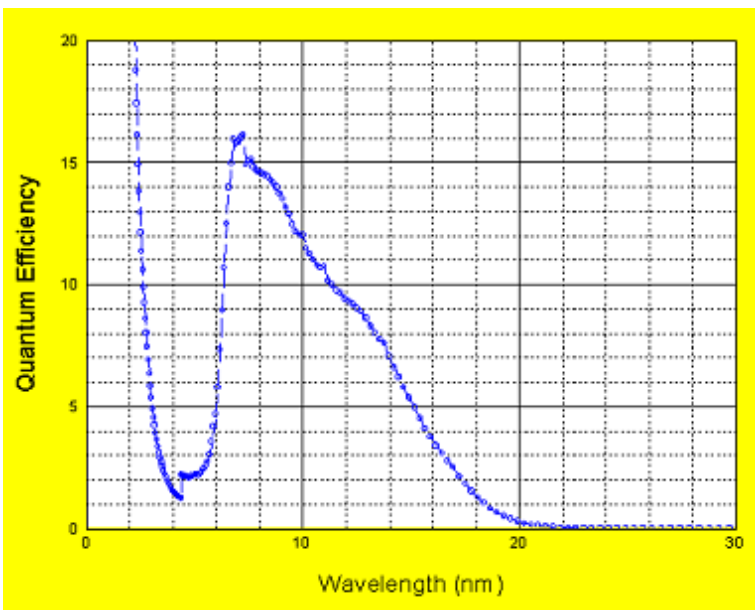


<Photo-detector>

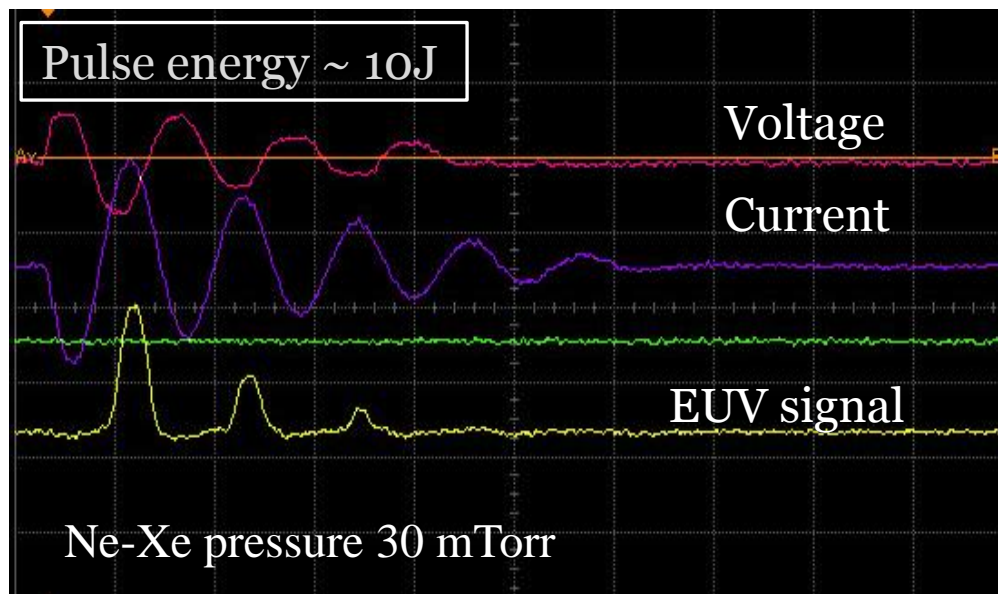


<Pre-amplifier>  
PA-100

EUV signal  
measurement

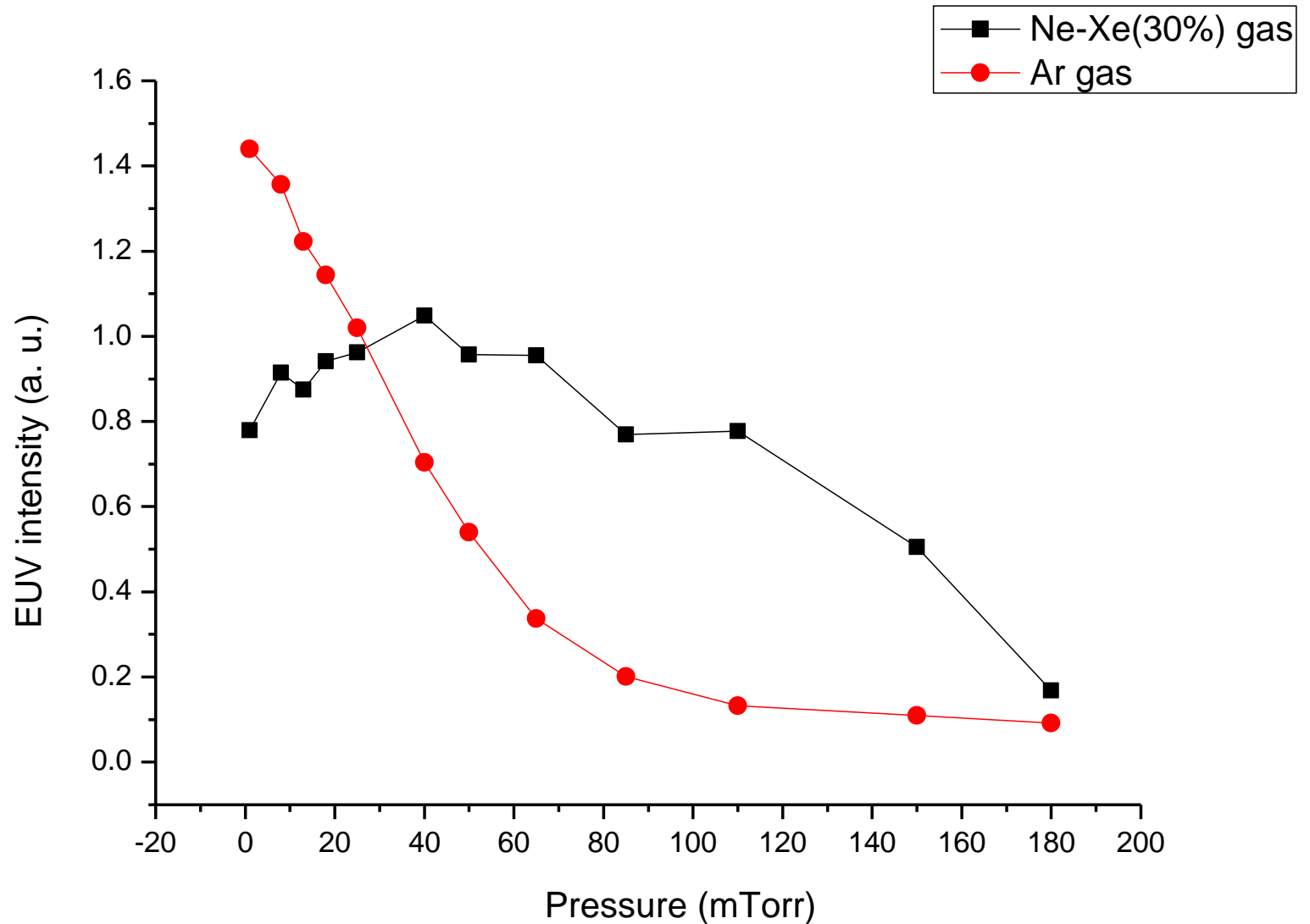


<Quantum efficiency of AXUV-100 Zr/C>



<experimental result>

# EUV intensity for Ar and Ne-Xe (30%) pressure



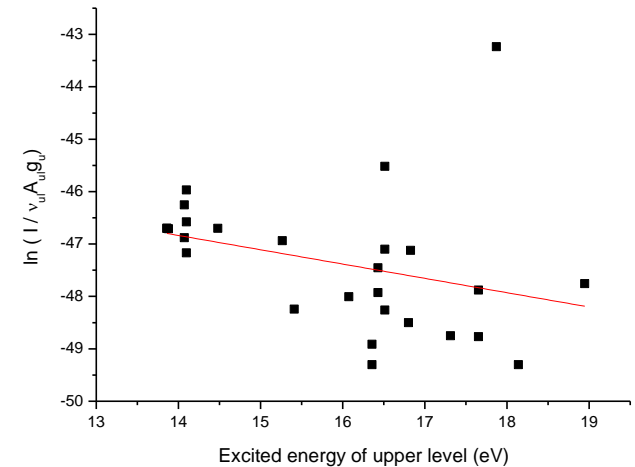
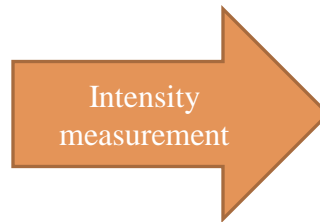
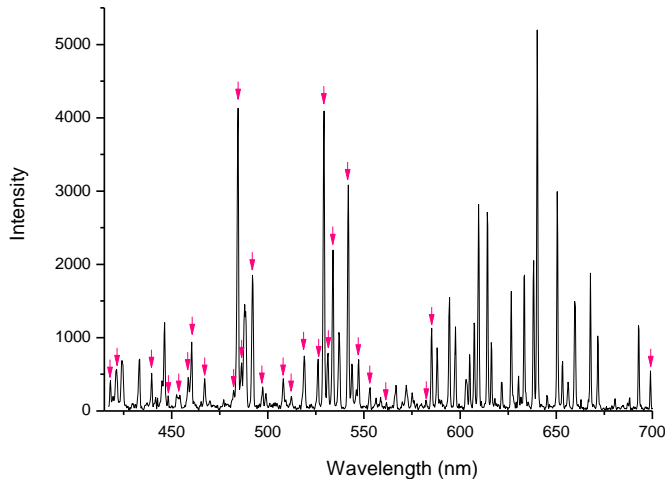
# Boltzmann plot method

The widely used method in determining the electron temperature is to make a Boltzmann plot using emission spectroscopy on the discharge plasma. Observing the intensity of emission spectrum lines, it provides the excitation temperature of the plasma. The Boltzmann plot uses several selected emission lines, providing an accurate value of electron temperature with an assumption of LTE. The intensity is proportion to the transition probability and the number of excited particles existing in the upper level energy. If the plasma is assumed to be in LTE, the Boltzmann distribution can be used to estimate the population of the excited state.

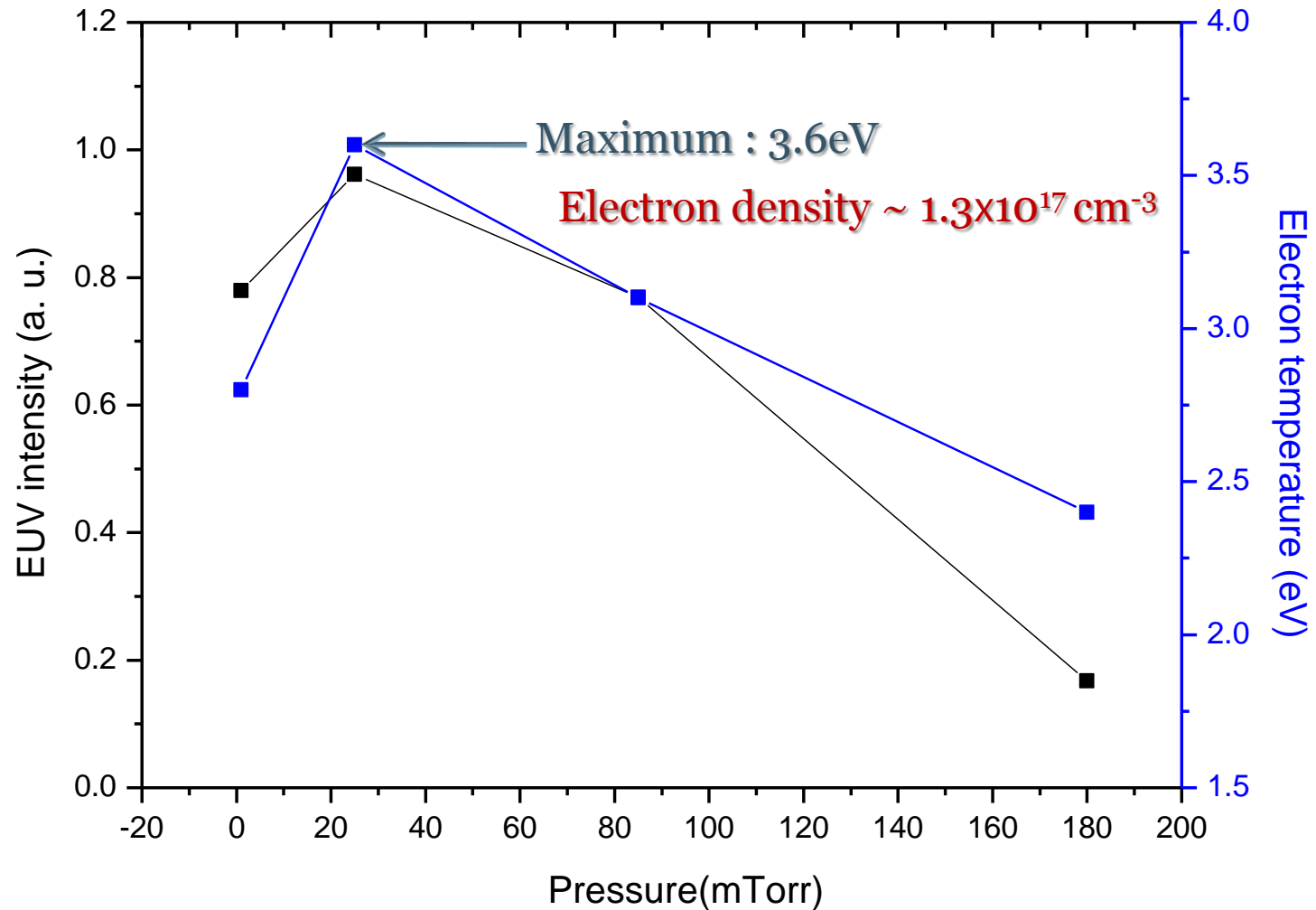
$$I = \frac{1}{4\pi} A_{ul} n h \nu_{ul} \frac{g_u}{Z} \exp\left(-\frac{E_u}{kT_e}\right)$$

, where  $E_u$  is excited energy of upper level,  $A_{ul}$  is transition probability,  $n$  is the population of the lower level,  $h$  is the Plank constant,  $\nu_{ul}$  is frequency of emission line,  $Z$  is the partition function,  $k$  is Boltzmann constant and  $T_e$  is the electron temperature. In order to evaluate the electron temperature, one takes the natural logarithm of

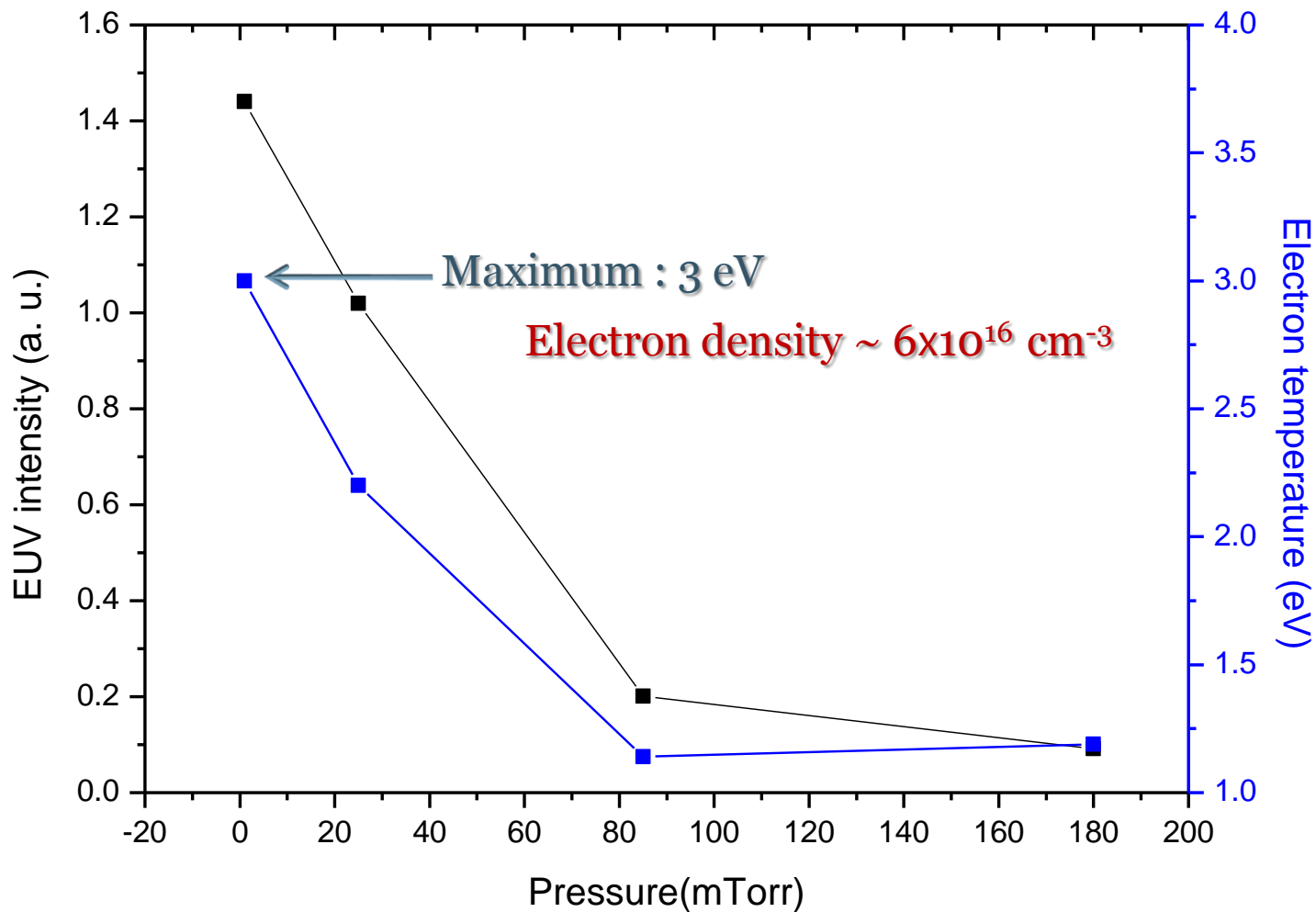
$$\ln\left(\frac{I}{\nu_{ul} A_{ul} g_u}\right) = -\frac{E_u}{kT_e} + \ln\left(\frac{hn}{4\pi Z}\right)$$



# Electron temperature and EUV intensity of Ne-Xe(30%)



# Electron temperature and EUV intensity of Ar



# Conclusion

- ❖ **Maximum  $kT_e = 3.6$  eV at Ne-Xe (30%), 25mTorr (Boltzmann plot)**
- ❖ **Maximum  $kT_e = 3$  eV at Ar, 1mTorr (Boltzmann plot)**
- ❖ **EUUV intensity and the electron temperature are mutually related.**

# Future work

- ❖ **The comparative experiment of Ar and Ar-Xe(30%)**
- ❖ **The comparative experimental on electron temperature of Ne and Xe in Ne-Xe(30%) gas**
- ❖ **The influence of Ne-Xe gas mixture ratio and measurement of electron temperature**
- ❖ **Measurement of the temporal behavior of electron temperature using Stark broadening**
- ❖ **Time integrated discharge image with pinhole camera**