Magnetic field ion mitigation for collector mirrors

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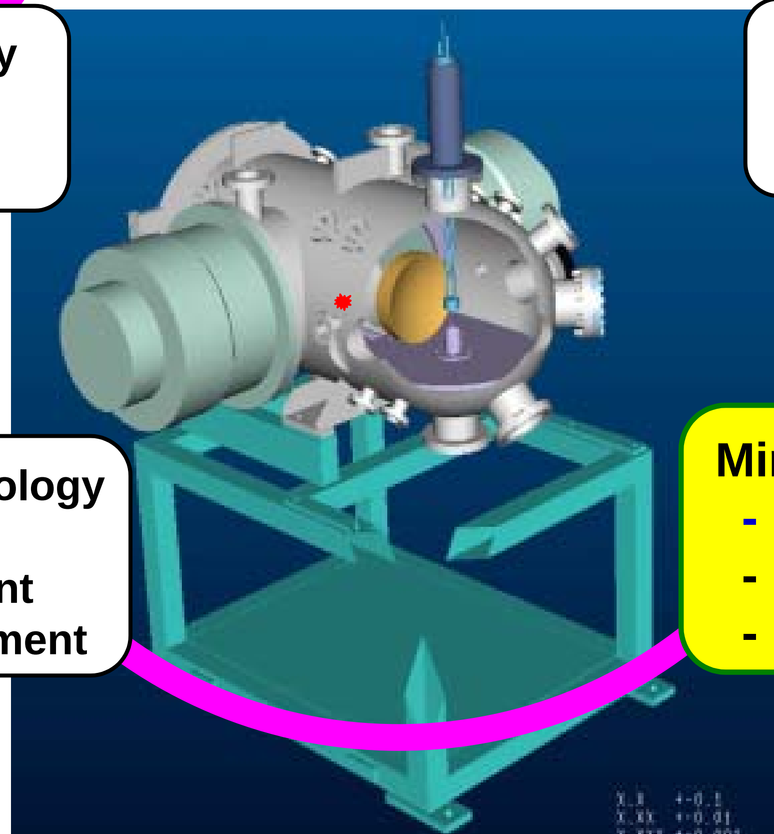
115W EUV Light Source

LPP-EUV light source
- High power/stability
- Long lifetime
- Low CoO

Target Technology
- High velocity
- High stability

Laser Technology
- High power
- Short Pulse duration



Chamber Technology
- High vacuum
- Small foot print
- Heat management

Mirror technology
- Long lifetime
- Large solid angle
- High reflectivity

Introduction

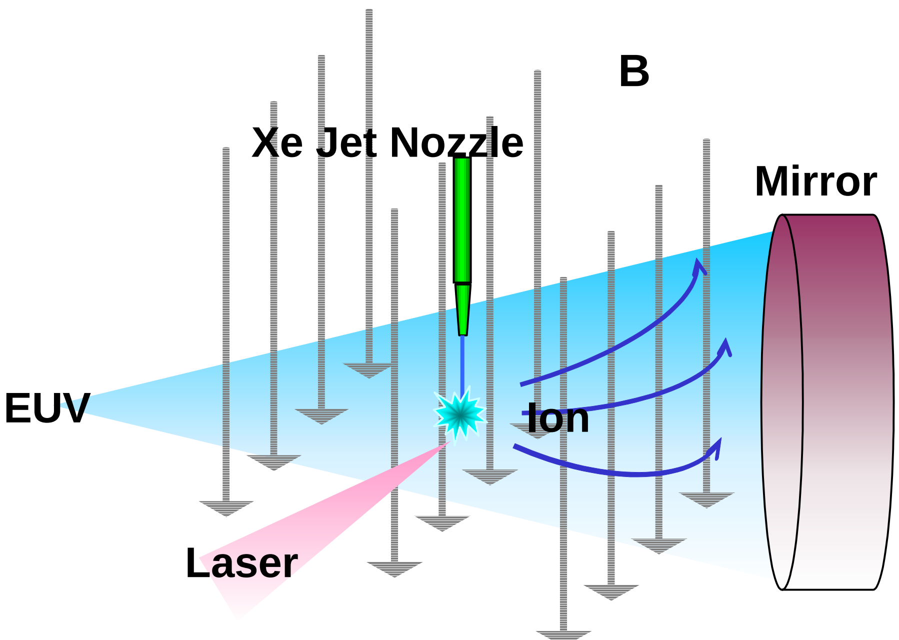
Development of collector mirror lifetime extension technology

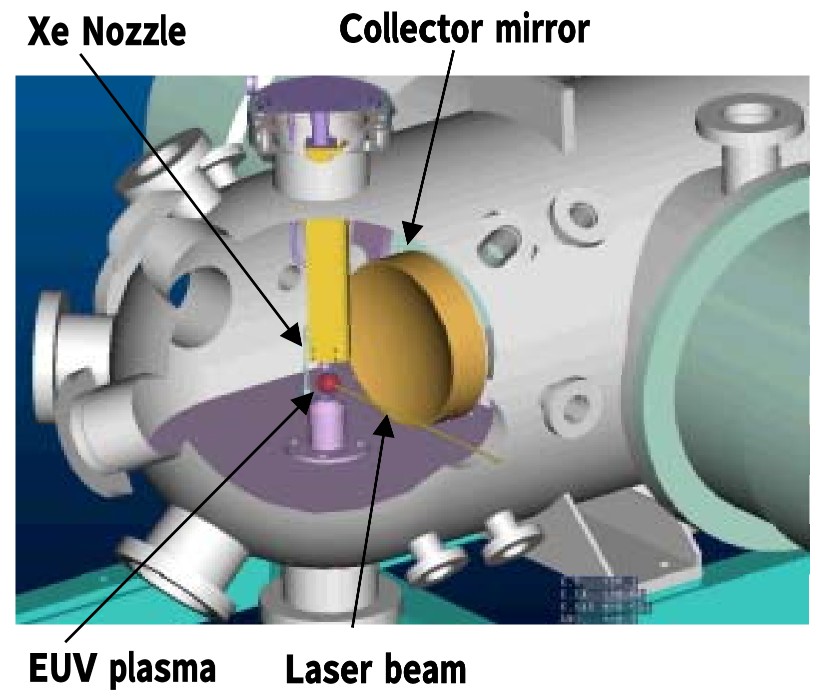
- **Collector Lifetime limitations :**
  1) EUV exposure, Heat load
  2) Cleanliness, Debris
  3) Fast ions

Contents

- **Magnetic field ion mitigation**
  Erosion rate was measured by QCM ➡ Reduced to 1/10
- **Characterization of ions from laser produced plasma**
  Time-of-flight (TOF) measurement ➡ Dependence on target size
- **Analysis of Xe plasma exposed multilayer sample**
  ➡ Boundary mixing, surface roughness increase
  EUV absorption by implanted Xe was negligible

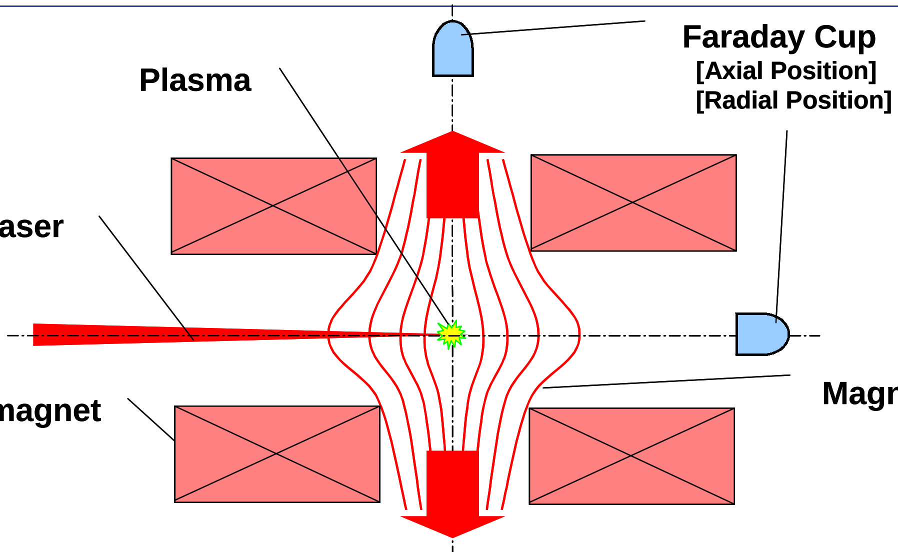
Concept of magnetic field ion mitigation





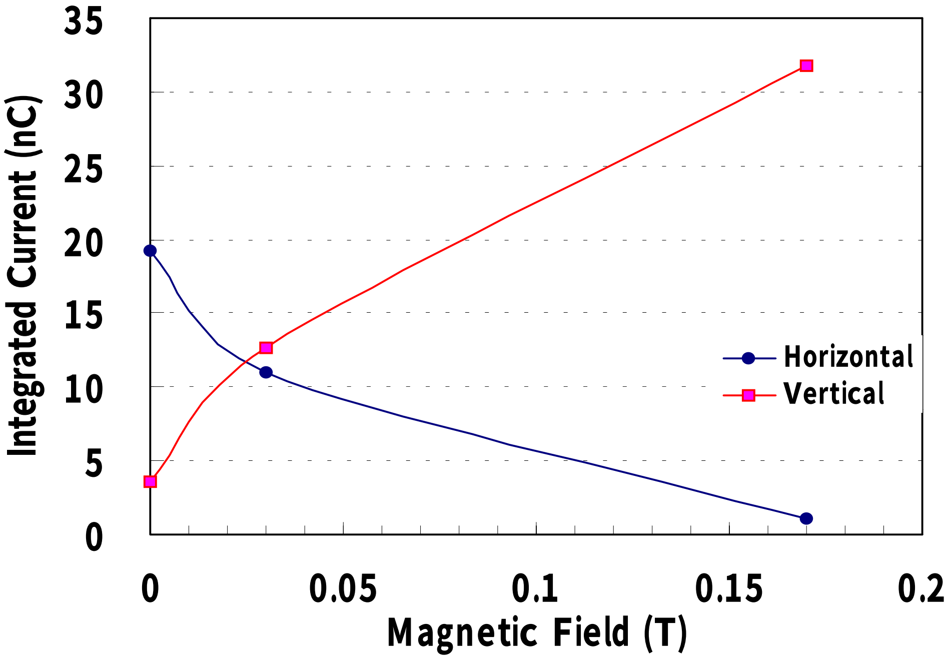
Effectiveness of magnetic field ion mitigation

Experimental setup



Laser: 200mJpulse
Target: Perfluoropolyether jet
Chamber Pressure: 0.5Pa

Faraday cup measurement



Magnetic ion mitigation for Xe jet target

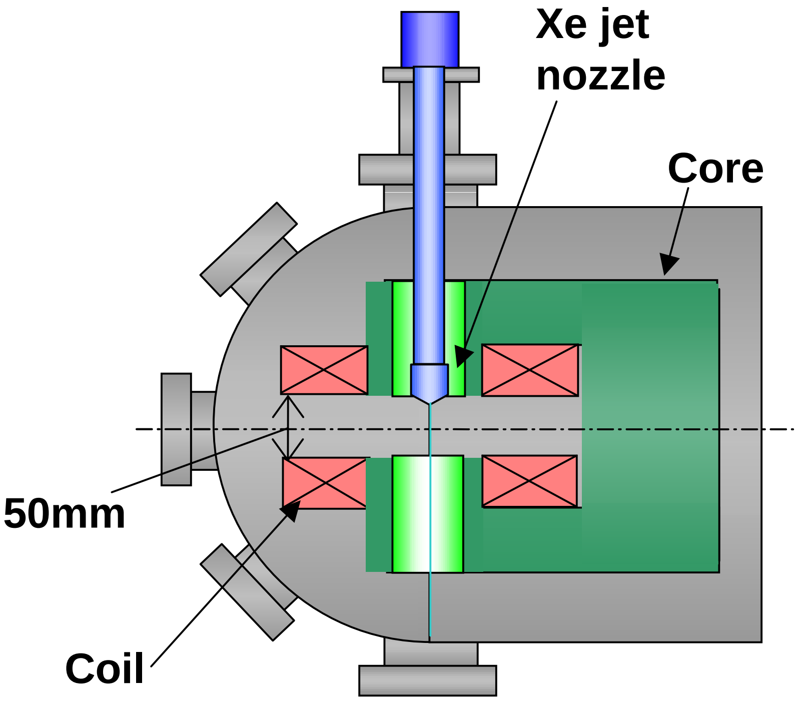
Estimation of required magnetic field

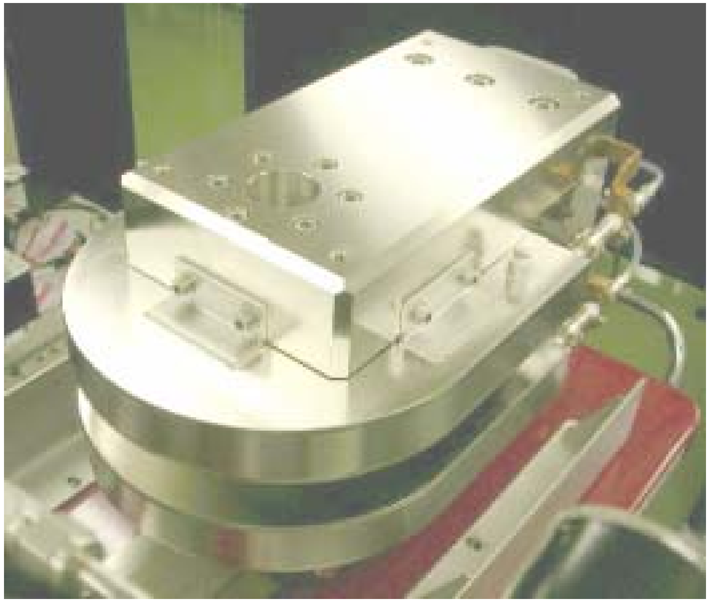
Larmor radius = mv / qB

- Xe atomic number 131
- Ion energy 3keV
- Xe ion charge state 2+
- Larmor radius 150mm

⇒ 0.3T

Item	Description
Magnetic flux density	0.6 T (center)
Coil diameter	390 mm
Coil distance	50 mm





Erosion monitoring by QCM

Quartz crystal micro balance (QCM)

Sample mass change is measured by monitoring the resonant frequency change of a quartz crystal

Sauerbrey equation $\Delta f = -C \times \Delta m$

Δf: frequency change, Δm: mass change, C: sensitivity factor

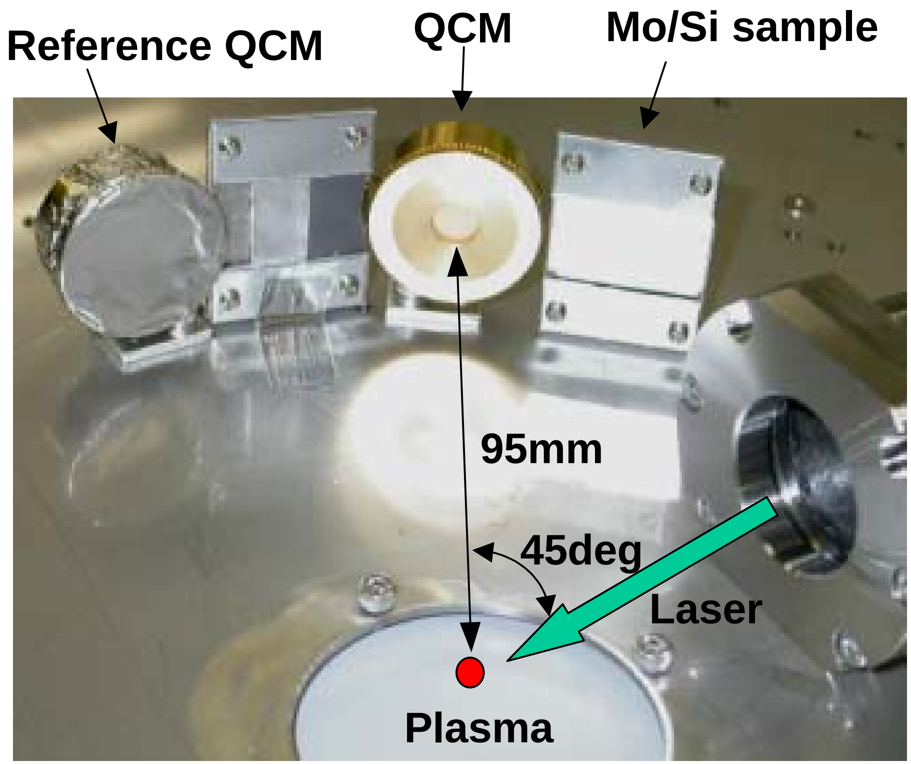
In-situ erosion monitoring

Ruzic et al, University of Illinois
Klebanoff et al, Sandia National Laboratories

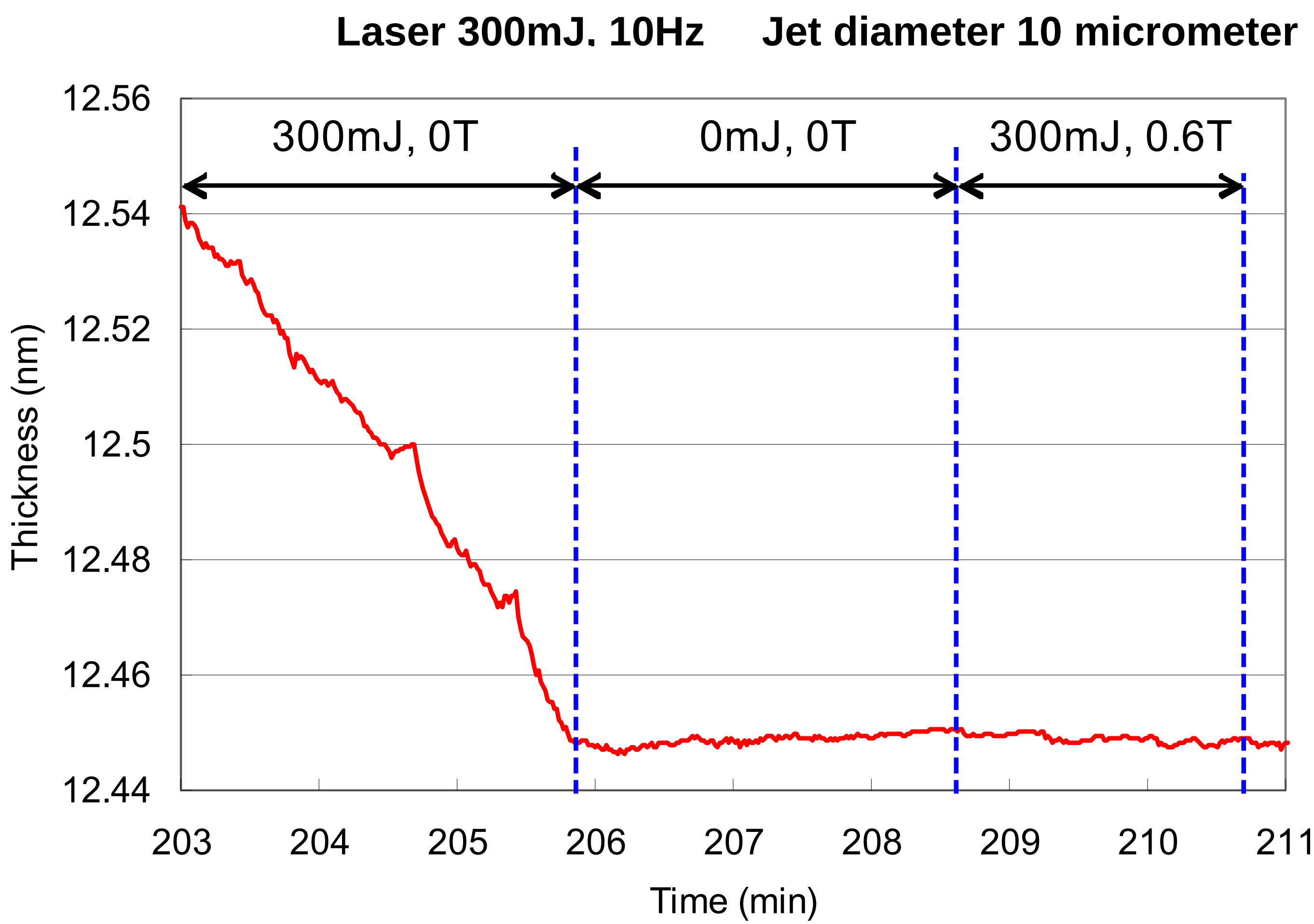
Sample configuration:
Sample-plasma 95mm

Laser: - 300mJ, 10Hz
Xe jet diameter: 10micrometer

QCM coating：Au
Sputter rate ratio Au:Mo:Si=10:2:1
(Klebanoff et al, Proc. of SPIE Vol. 5342, p710)
=6:2:1
(for 600eV, Xe^+; Vacuum Handbook in Japanese)



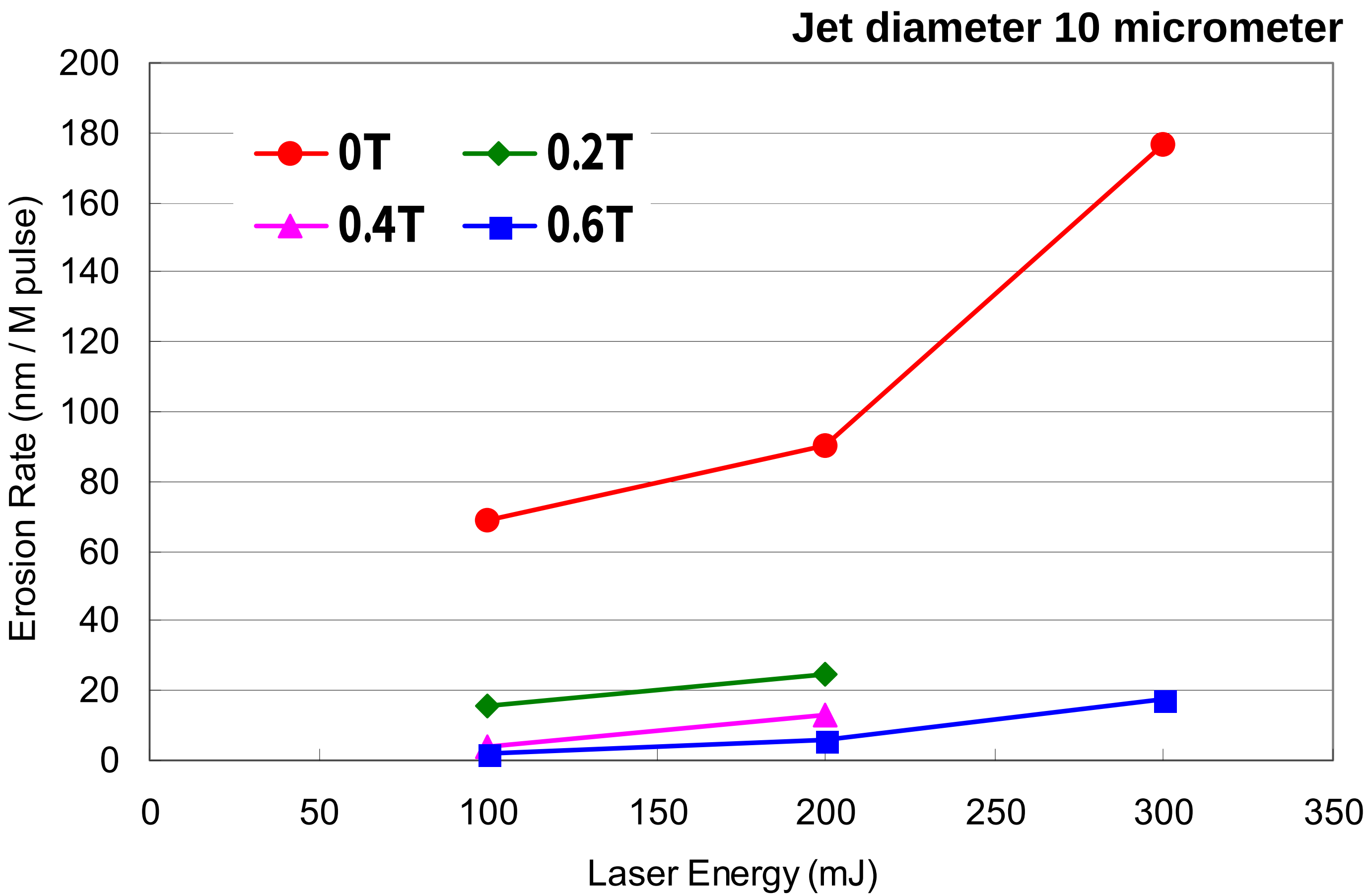
Ion mitigation effectiveness measurement by QCM



Effectiveness of Magnetic field was measured by QCM

Ion mitigation effectiveness measurement by QCM

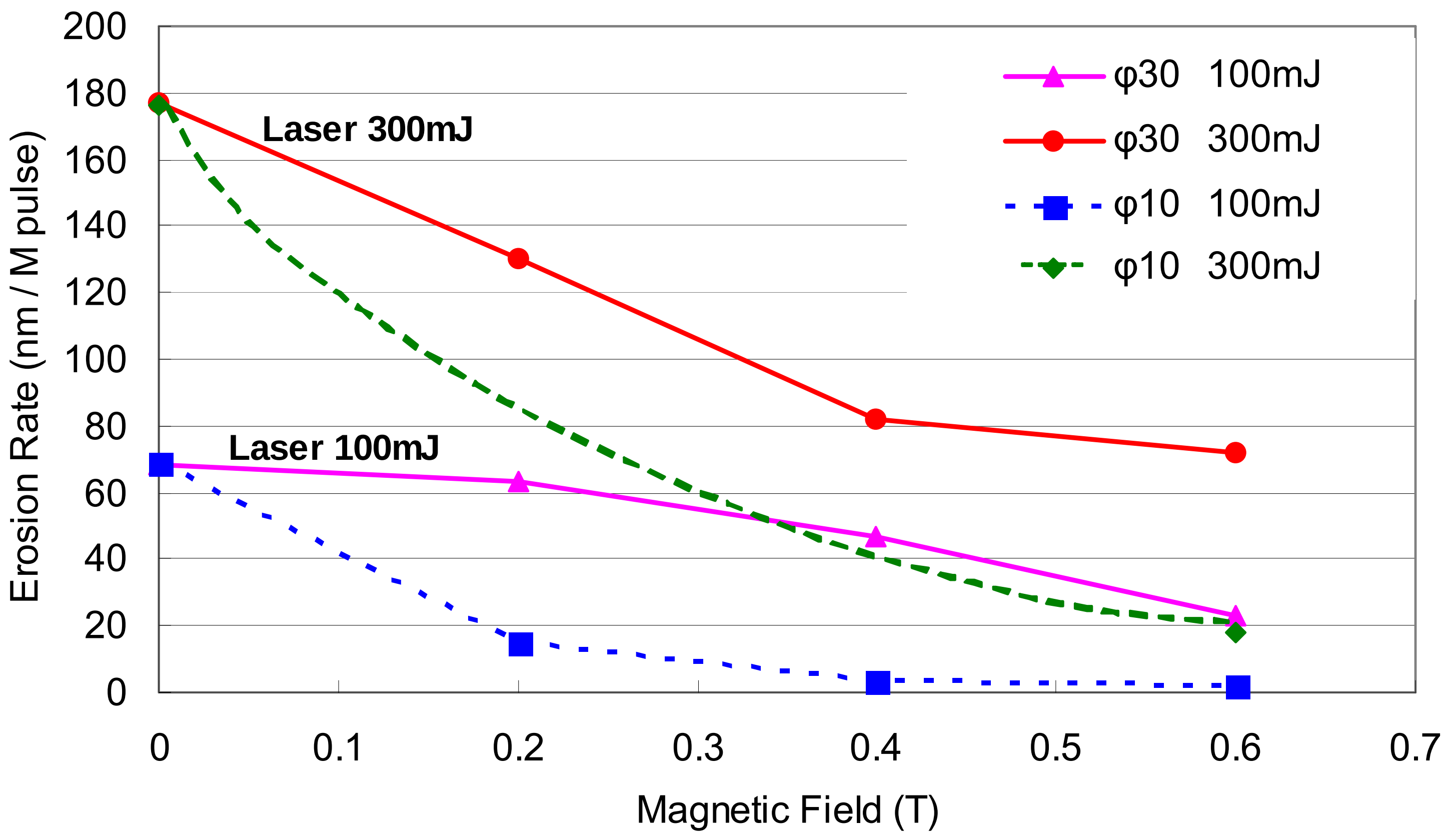
Erosion rate dependence on magnetic field and laser energy



Erosion rate was reduced to 10% by applying 0.6T magnetic field

Estimated life : 10 M pulse ➡ >100 M pulse (20 bilayer lost, 150mJ, 10Hz)

Magnetic ion mitigation dependence on target size

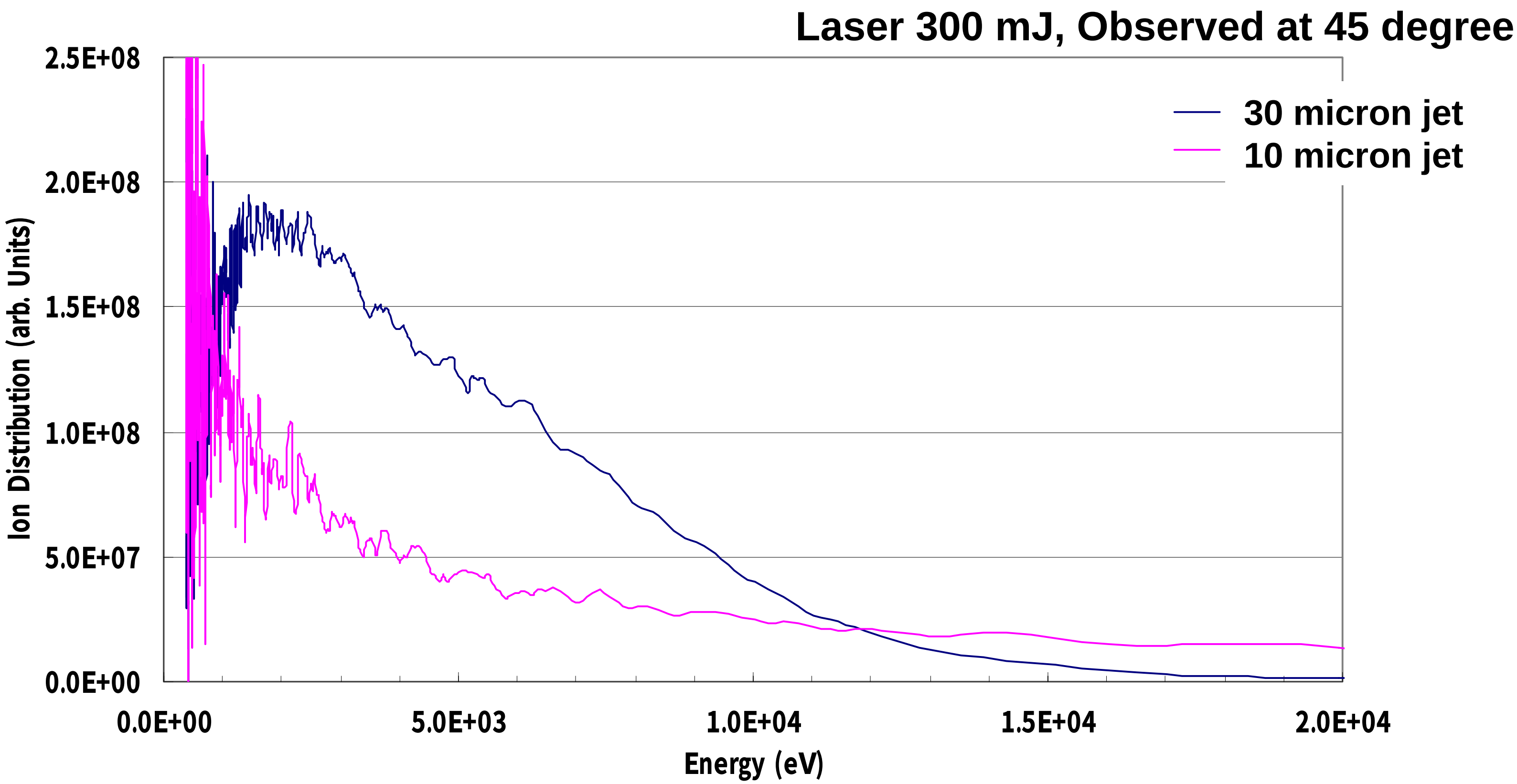


10 micrometer jet: reduce to 10% (Chamber pressure 0.03Pa)
30 micrometer jet: reduce to 40% (Chamber pressure 0.2Pa)

Neutral particles generation by collisional charge transfer ?

Characterization of fast ions from laser produced plasma

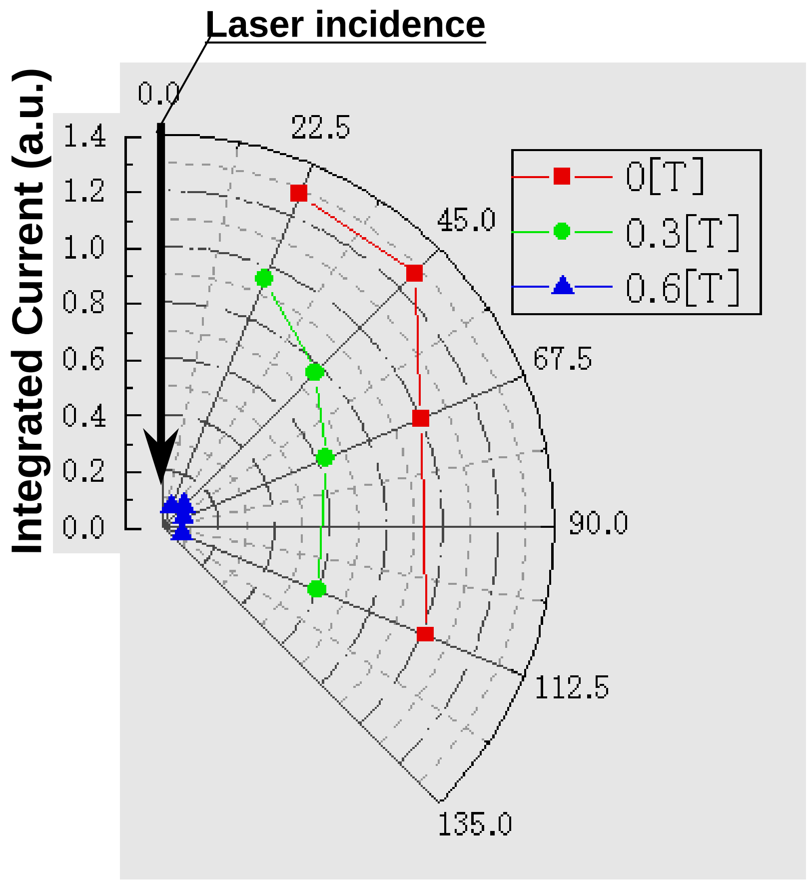
TOF data dependence on Xe target size



Target size dependence of Xe ion energy distribution was observed
High energy ions were detected with 10 micrometer jet

Ion distribution in Magnetic field

Angular distribution measured by a Faraday cup



Laser: 100mJ, 10Hz
Xe jet diameter: 10micrometer

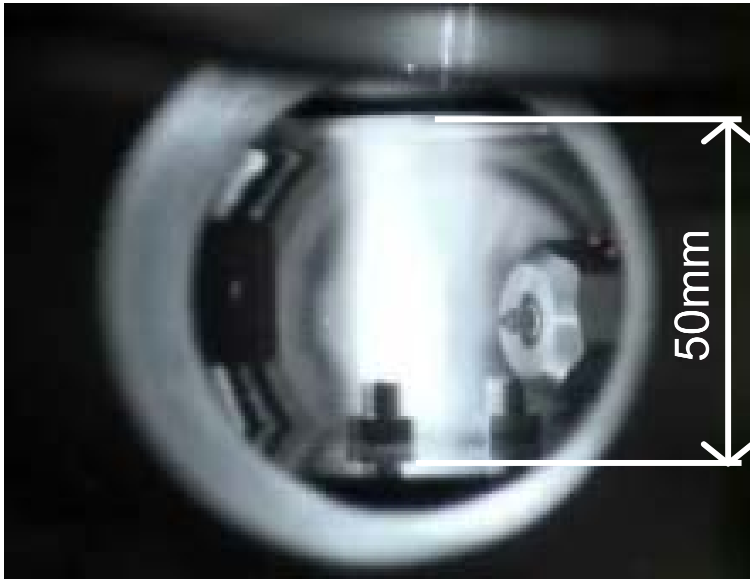
Total charge was significantly decreased with magnetic field of 0.3-0.6T

Ion distribution in Magnetic field

Visible image of a plasma with and without a magnetic field

0 T

0.6 T

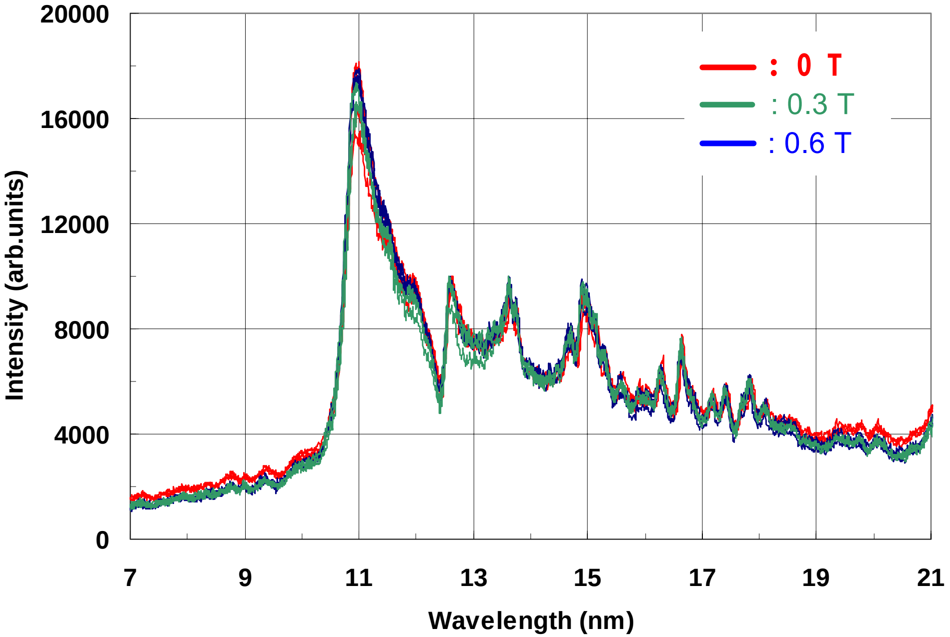


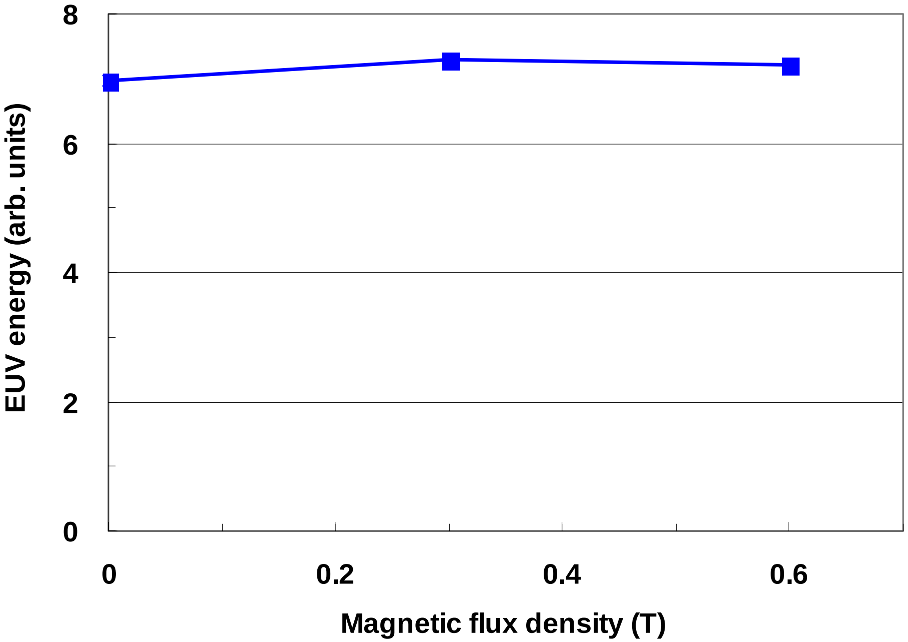
Jet diameter：30 micrometer
Laser: 100 mJ
Chamber pressure: 0.3 Pa

Positive column was observed by applying magnetic field

Magnetic field effect on EUV out put

EUV spectrum and energy with and without a magnetic field





Jet diameter：30 micrometer
Laser: 100 mJ
Chamber pressure: 0.3 Pa

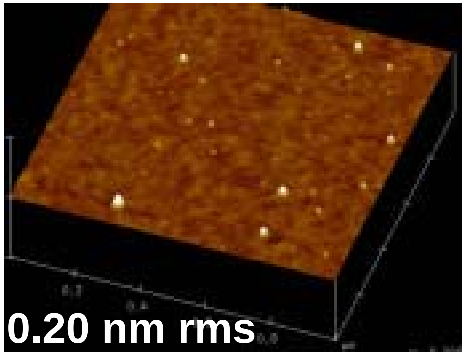
No change in EUV spectrum and EUV energy by magnetic field

Multilayer sample analysis

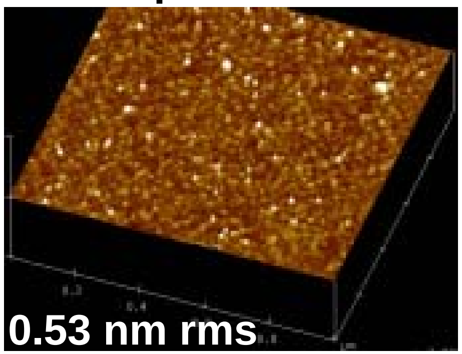
AFM

(10x10 micrometer)

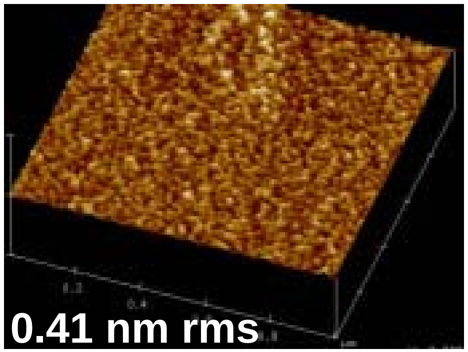
Reference



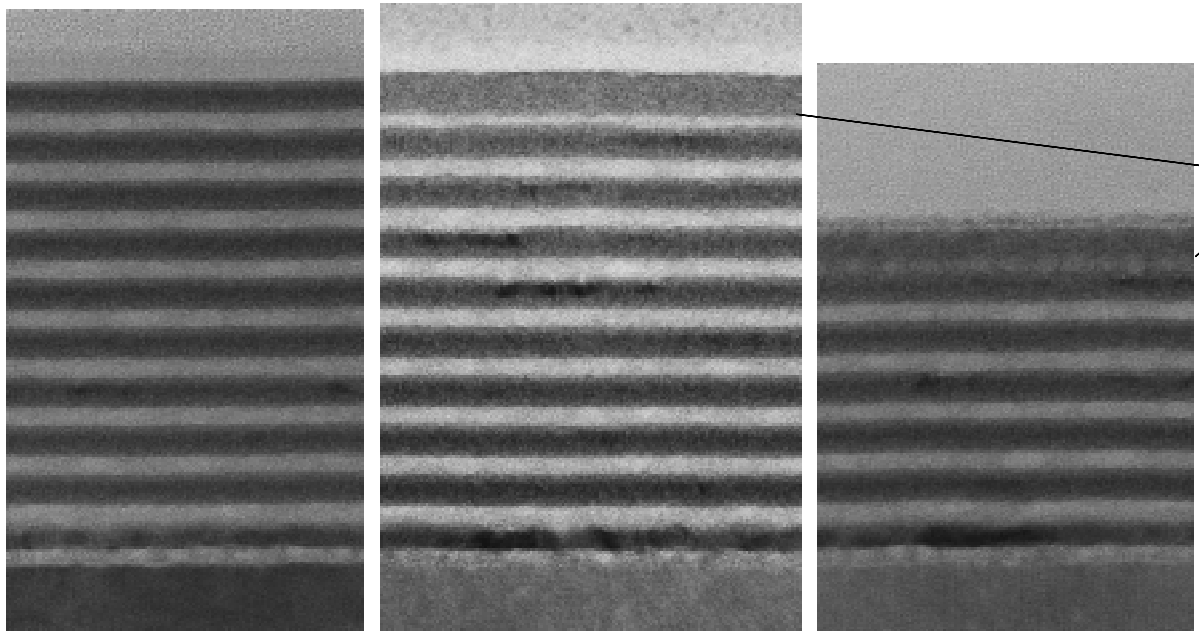
LPP Xe plasma



Xe ion gun exposure



TEM



Mixing

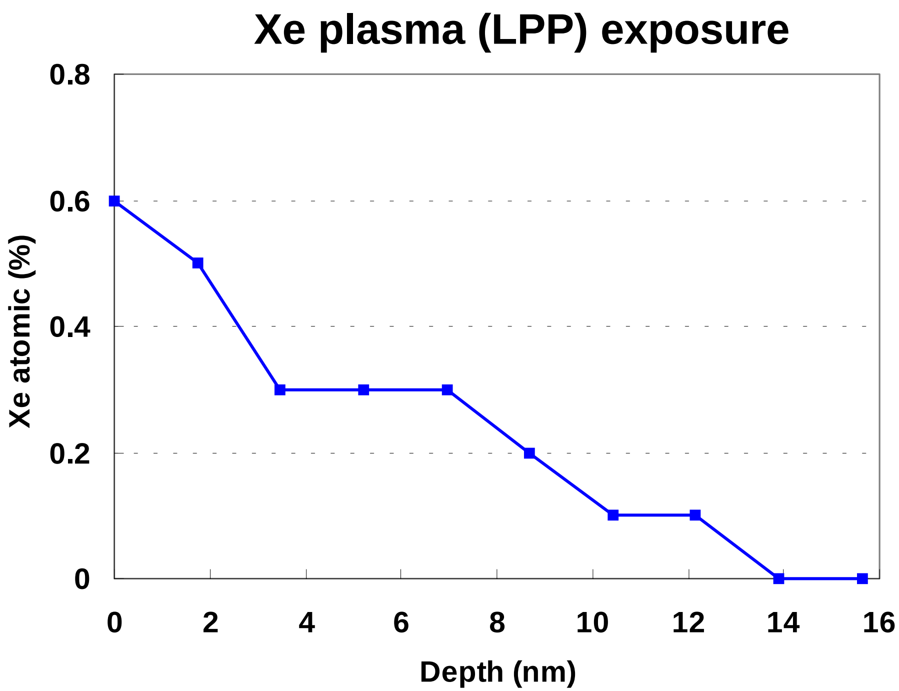
10 Mo/Si bilayer

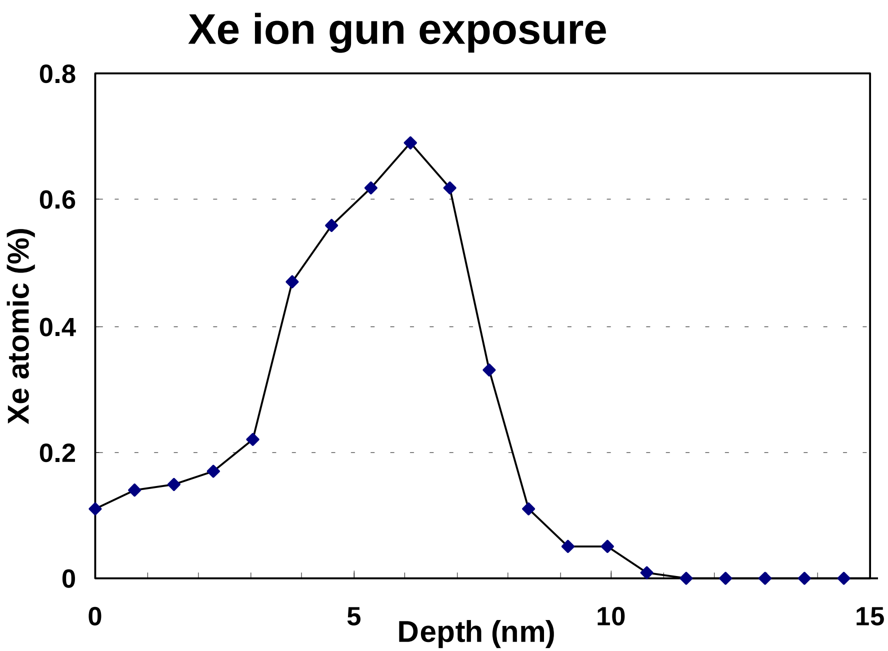
Laser energy 300mJ
0.16 M pulse

Ion energy 5 keV
Ion dose 2.8 X 10^{16} atoms/cm^2

Multilayer sample analysis

Implanted Xe analysis by XPS (X-ray Photoelectron Spectroscopy)





Xe atomic % : 0.6% peak
Total depth : 14 nm

Absorption at 13.5 nm by implanted Xe is negligible (<0.5%)

Summary

Effectiveness of magnetic field Ion mitigation has been demonstrated

- Erosion was monitored in-situ by QCM (Quartz crystal micro balance).
- Erosion rate was reduced to 10% by applying 0.6T magnetic field.
- No change in EUV spectrum and EUV energy by magnetic field.
- Target size dependence of Xe ion energy distribution was observed.
- Boundary mixing near surface and surface roughness increase was observed.
- EUV absorption by implanted Xe is negligible.

Acknowledgements

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