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# EQ-10 EUV Source for Metrology Applications

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# Key Requirements for a Metrology Source

- High Brightness
- Excellent Spatial Stability
- High Pulse-Pulse Stability
- High System Reliability

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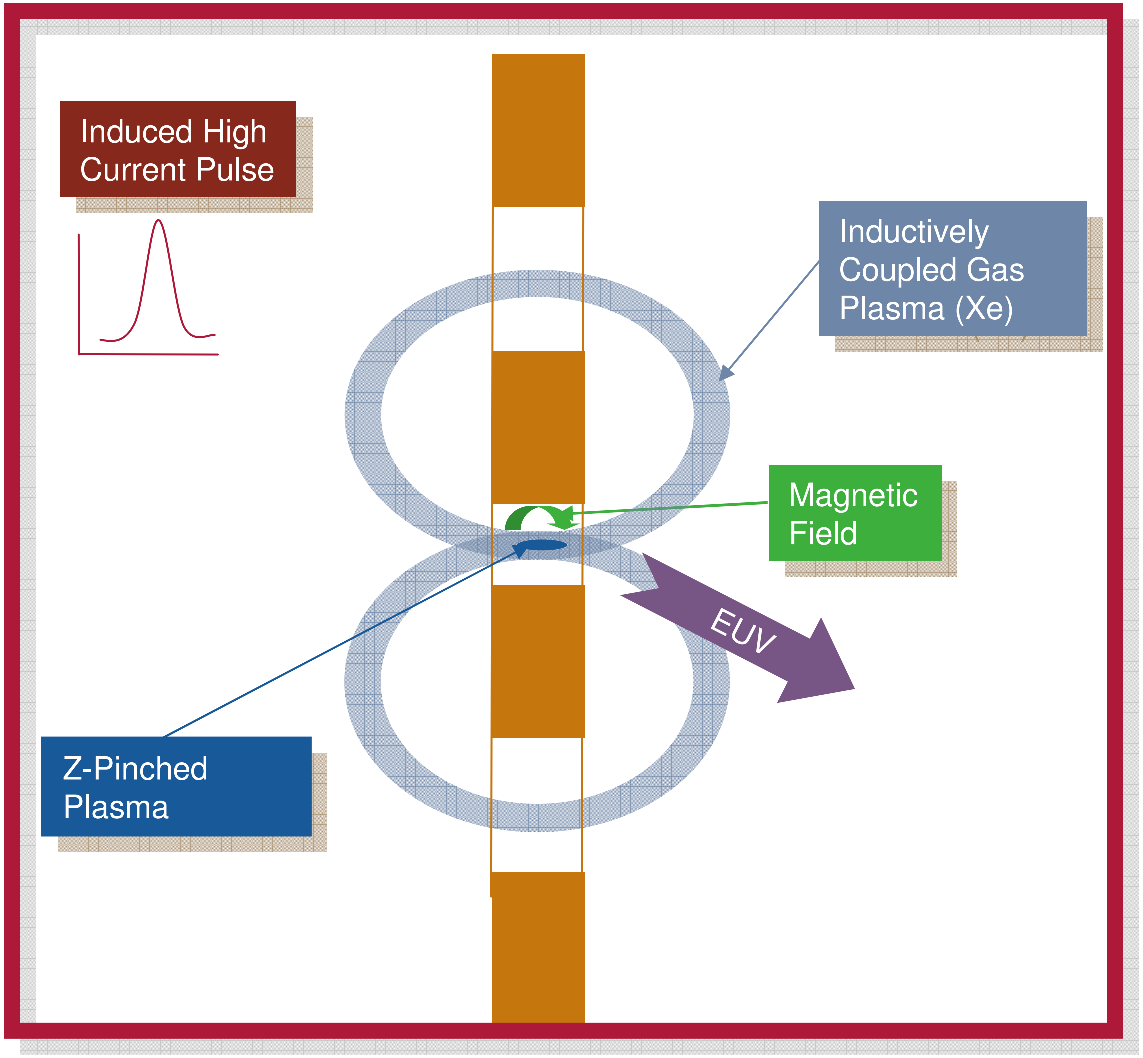
# EQ-10 Source

- Introduced in 2005
- 13.5nm ±1% Power in 2π
  - 10W continuously
  - Now 20W
  - @2 kHZ
- 10kHz operation also
- Operates continuously for days and weeks

Semiconductor International
Editors' Choice
Best Product 2008

R&D 100

# Electrodeless Z-Pinch

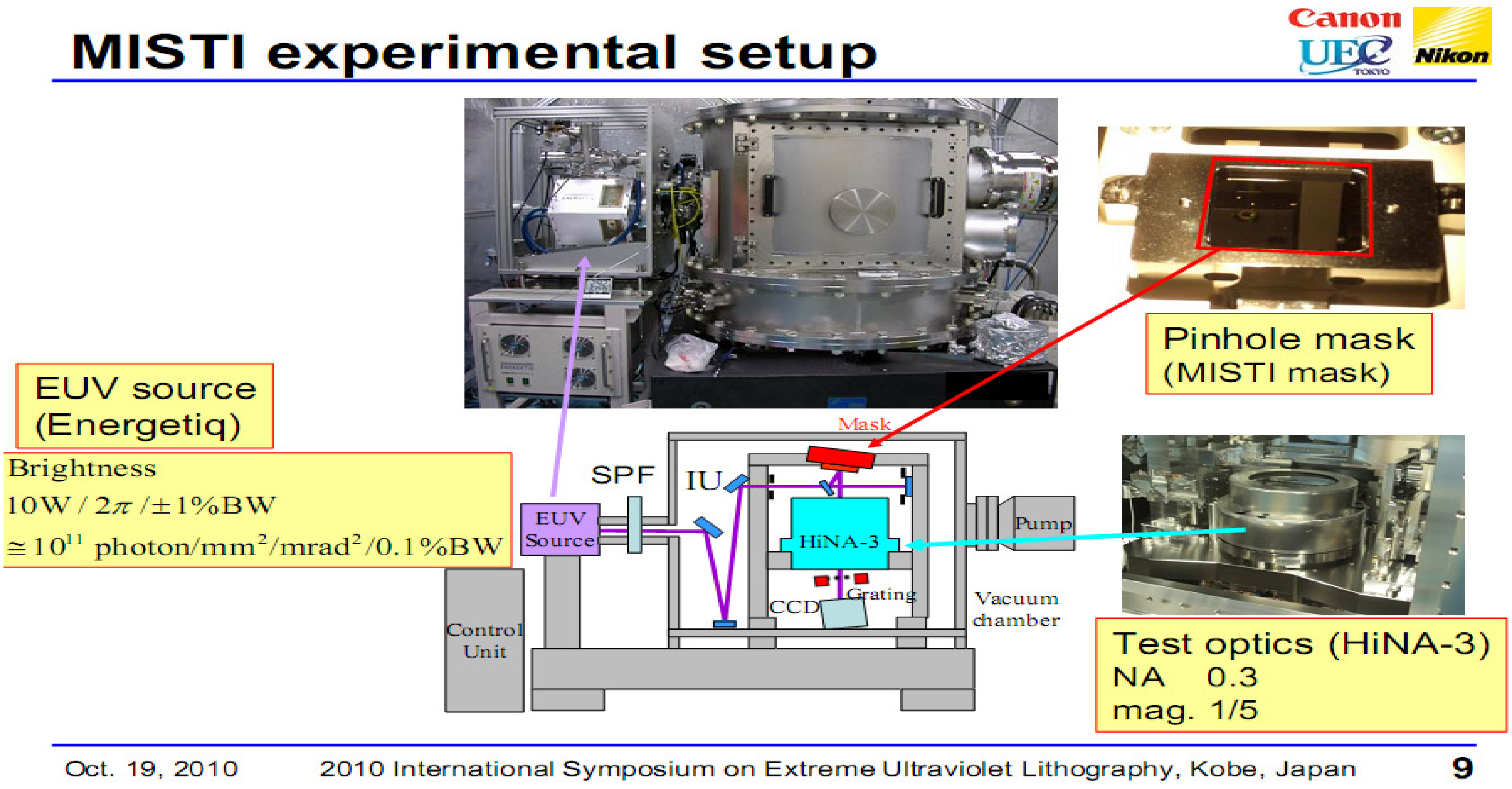


- Inductive design eliminates electrodes and electrode current
- Plasma is magnetically confined away from source components and ‘pinned’ electromagnetically to the geometric center of the bore

# System Reliability

- Shipped over 15 sources in the field
- Installations in Japan, Europe and US
- Systems being operated 24/7 with minimal downtime
  - One system has many 10s of billions of pulses at 2kHz at 24/7 operation
- Systems integrated into tools for research and development
  - Actinic Inspection
  - Resist Outgassing
  - Mask Contamination
  - Optics Testing

# Wavefront Metrology Tool
# Optics Testing



## MISTI experimental setup

EUV source
(Energetiq)

Brightness
10W / $2\pi$ /$\pm$1%BW
$\cong 10^{11}$ photon/mm$^2$/mrad$^2$/0.1%BW

Pinhole mask
(MISTI mask)

Test optics (HiNA-3)
NA 0.3
mag. 1/5

Oct. 19, 2010 2010 International Symposium on Extreme Ultraviolet Lithography, Kobe, Japan 9

# Actinic Mask Defect Detection Tool at MIRAI-Selete

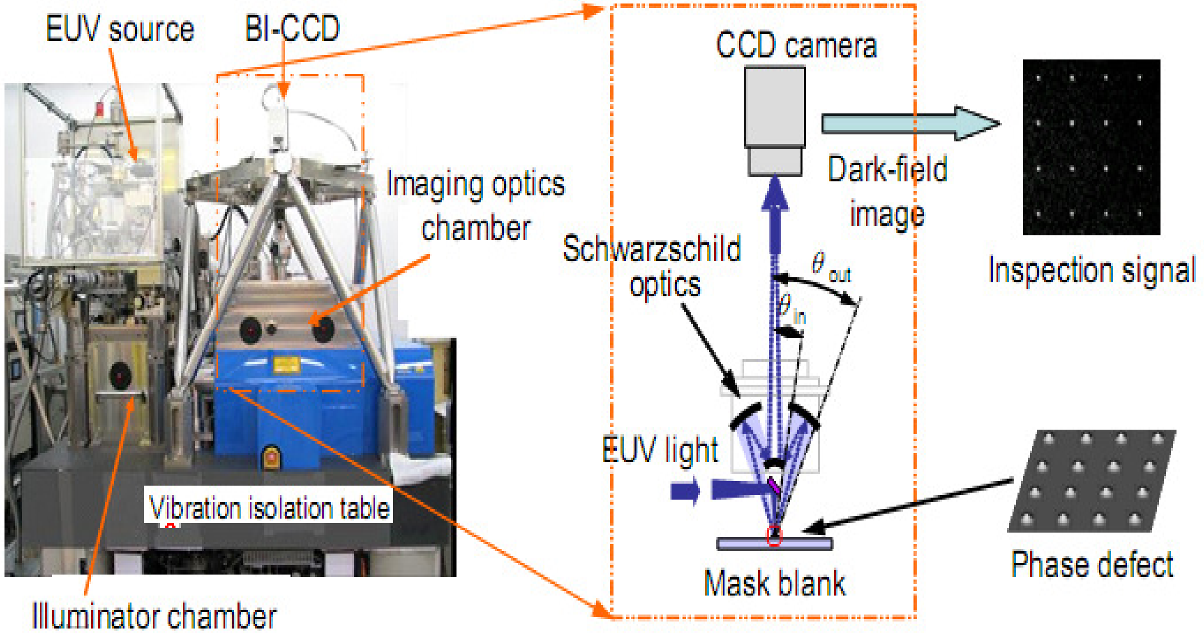


Figure 2 Actinic mask blank inspection tool built at MIRAI-Selete clean room and concept of its inspection optics using dark-field imaging.

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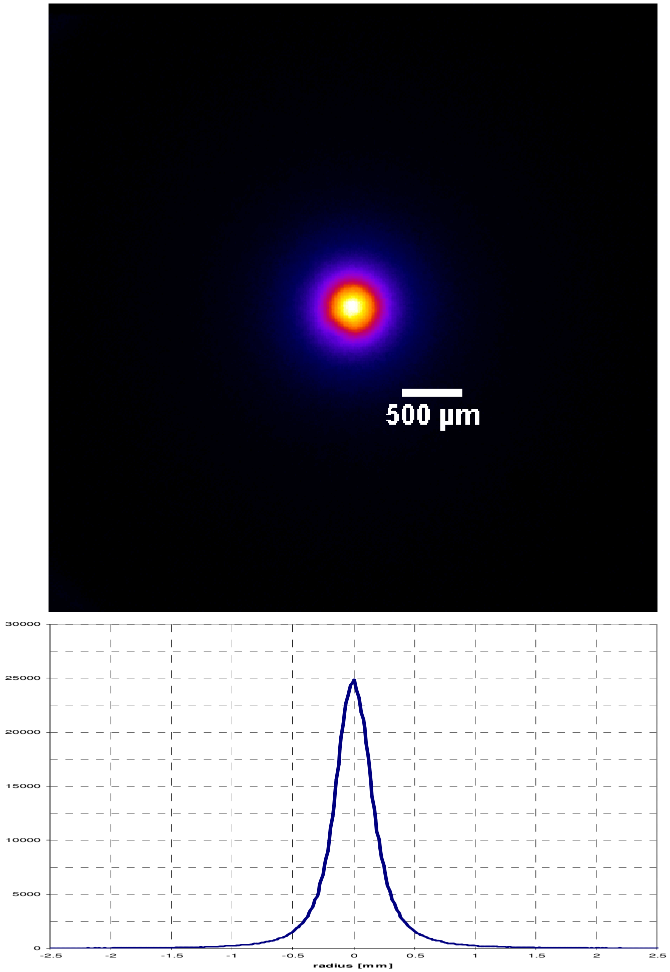
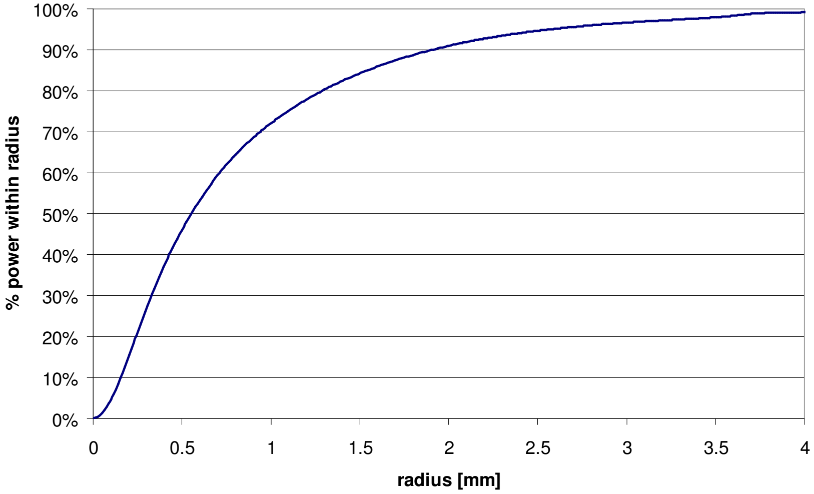
# Recent Improvements in EQ-10 Brightness and Power

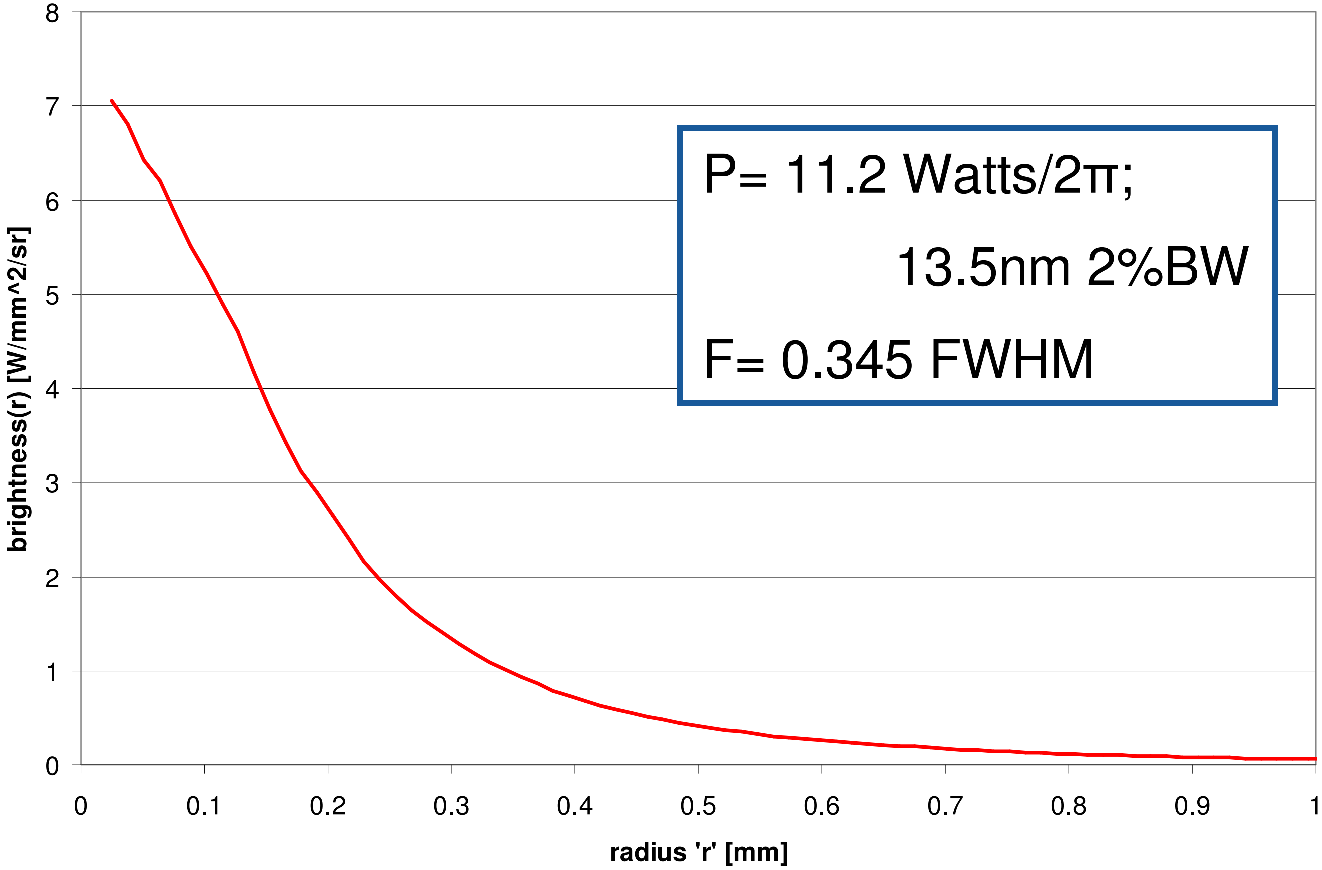
# EQ-10 in-band EUV Brightness



- Brightness is a function of power and radius



# Brightness as function of radius Standard EQ-10

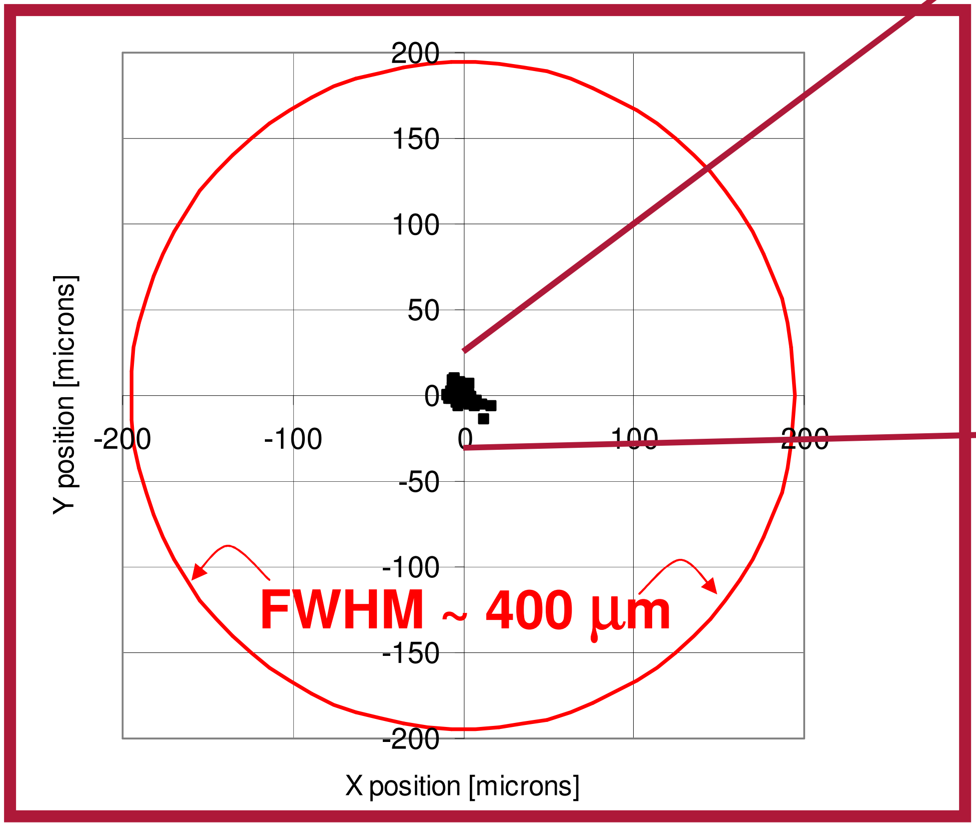


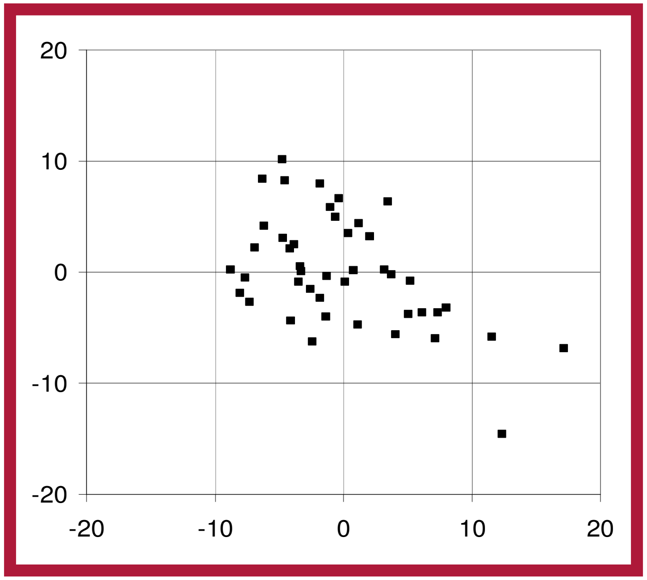
P= 11.2 Watts/2π; 13.5nm 2%BW

F= 0.345 FWHM

# Stability in EUV Plasma Position

- Image recorded once an hour for over 300 million pulses (~44hours) of continuous operation. Position then extracted from images:
  - Position: **$\sigma_x$= 5.8 µm** and **$\sigma_y$= 5.0 µm**

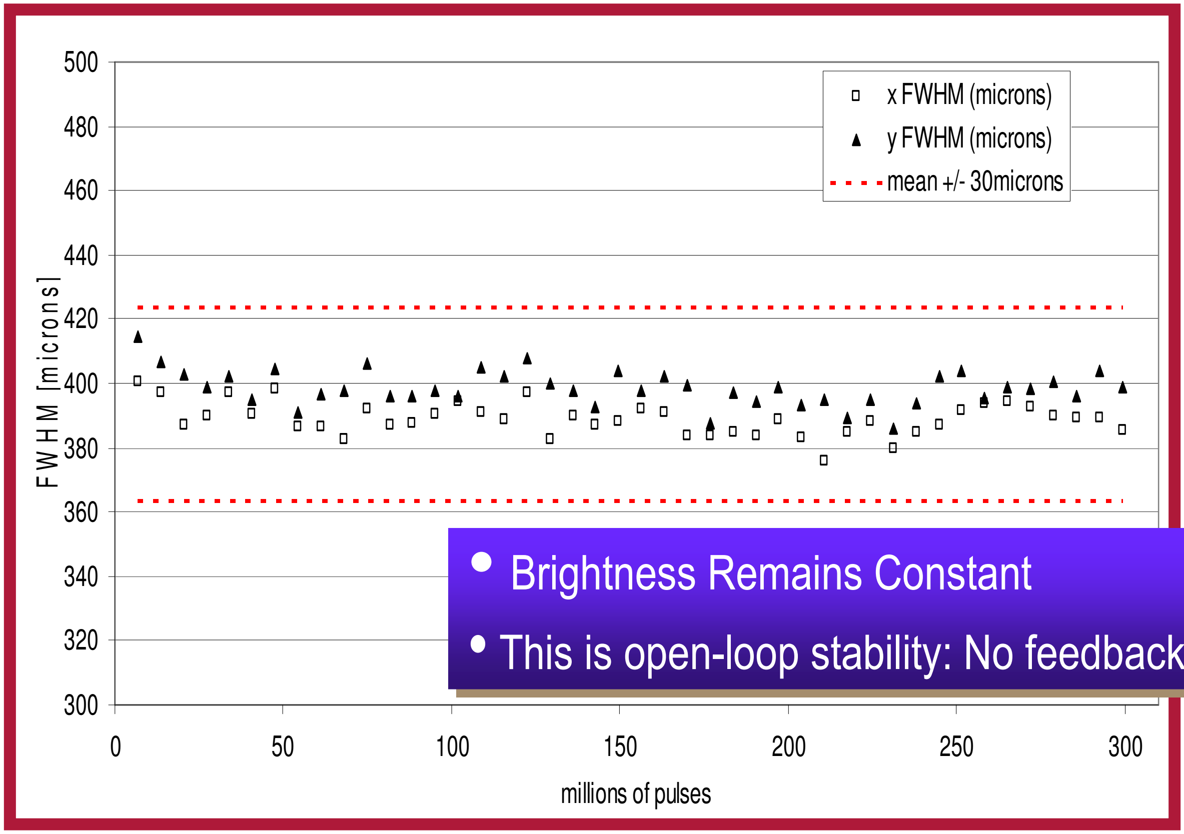




- Brightness remains constant
- This is open-loop stability: No feedback!

# Stability in EUV Plasma Size

- Image recorded once an hour for over 300 million pulses (~44hours) of continuous operation. Size then extracted from images:
  - Size: **$\sigma_{FWHMx}$= 3.1 μm** and **$\sigma_{FWHMy}$= 3.6 μm**

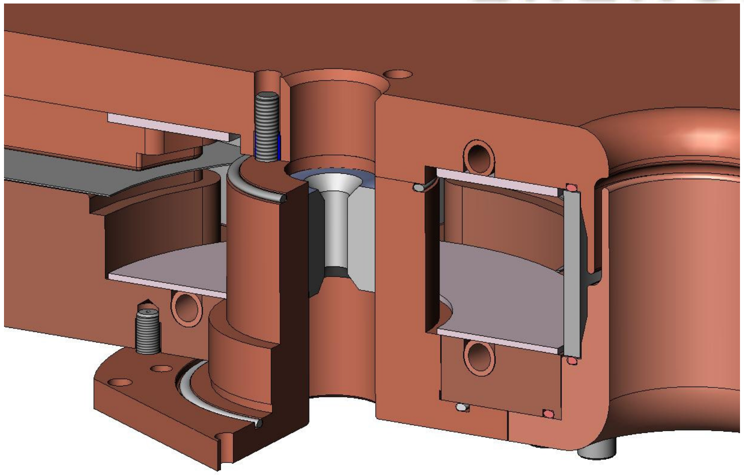


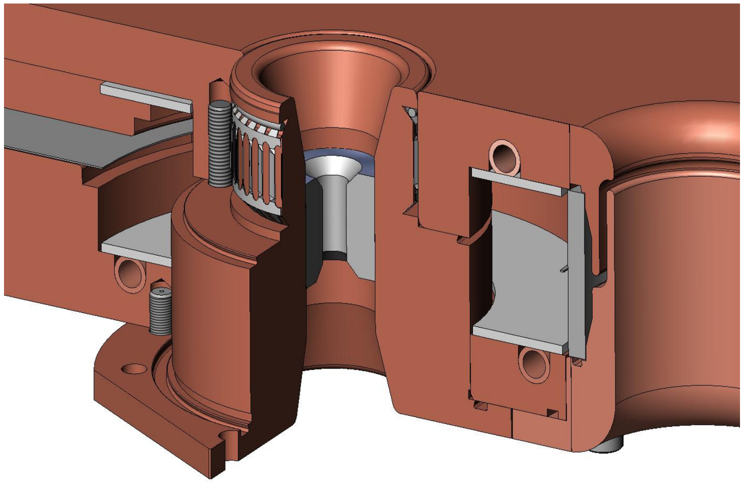
- Brightness Remains Constant
- This is open-loop stability: No feedback!

# Redesigned Source

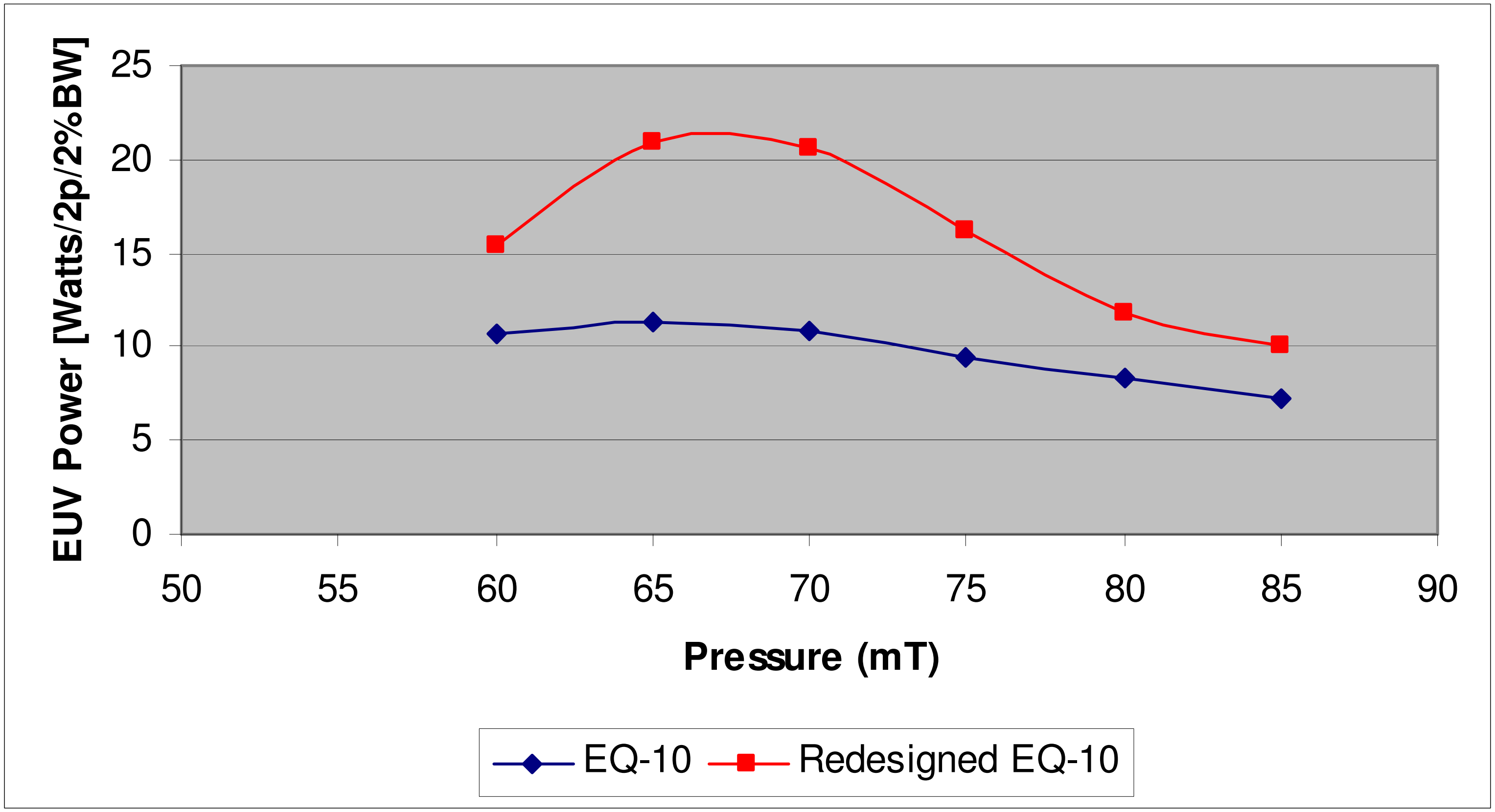
Advantages for new design

- All surfaces exposed to plasma pinch are replaced with bore exchange
- High current capacity contact insert
  - plasma erosion at contact area reduced
  - More consistent electrical contact
- Improved cooling for bore insert



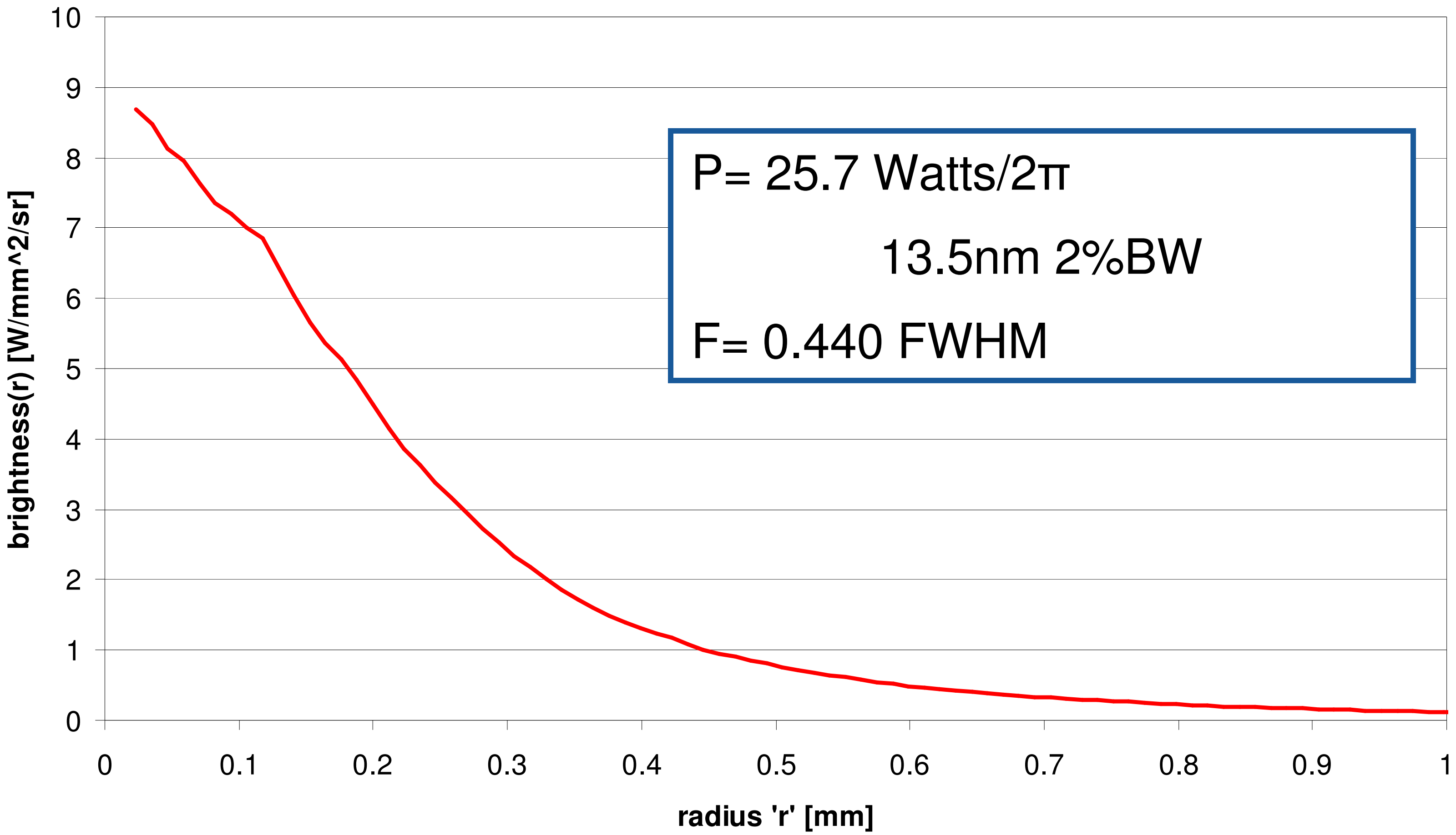


# Increased Power with New Source Design



280V 1900Hz – Standard Operating Conditions

# Increased Brightness New Source



P= 25.7 Watts/2π

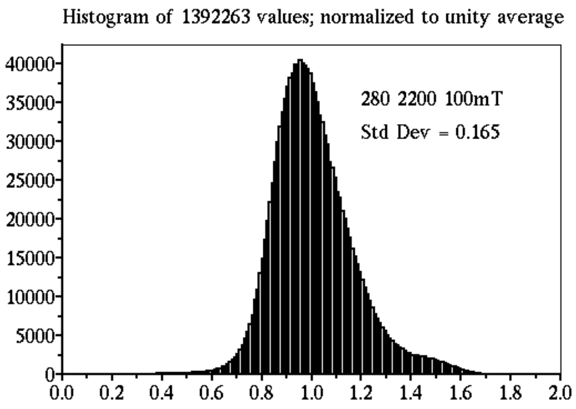
13.5nm 2%BW

F= 0.440 FWHM

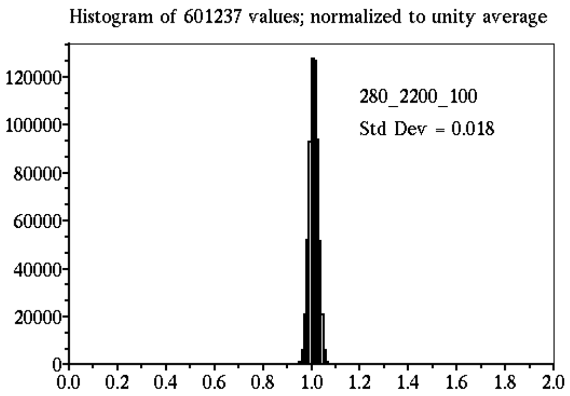
# Improvements to Pulse Modulator

- **The modulator was recently redesigned to improve power handling and stability.**
- **The redesign is to force the compression stages to a well-defined state prior to each charging cycle, thus reducing or eliminating this source of variability**

- Pulse to pulse stability with Original Modulator – ~16%



- Pulse to pulse stability with redesigned Modulator ~2%



- Conditions: 280V,2200Hz,100mT

# Key Requirements for a Metrology Source

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- √High System Reliability

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# Closing Remarks

- The Energetiq EQ-10 EUV source is a reliable and stable source of EUV photons.
- The system is being operated in the field 24/7 with consistent operation over years!
- Energetiq Sources are being used for infrastructure development globally.
- Redesign of the source offers higher power and higher brightness operation
  - Brightness of ~8W/mm^2-sr
  - 20W/ 2π
  - Improved pulse-to-pulse stability
  - Continued excellent plasma stability

# Acknowledgements

- The team at Energetiq…
- Our valued customers…
- Our excellent partners and collaborators…