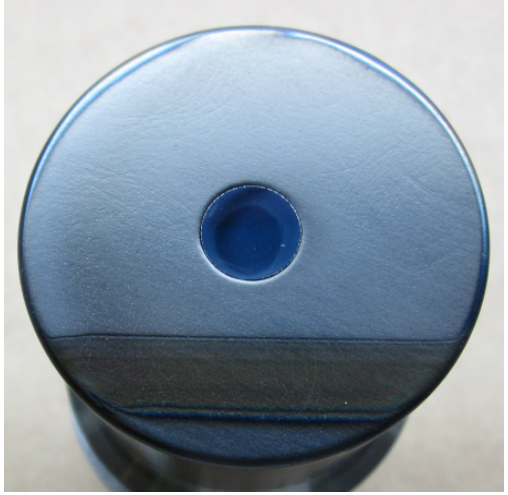
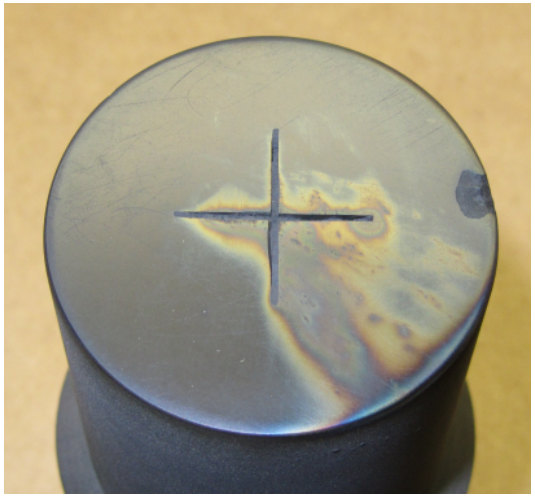
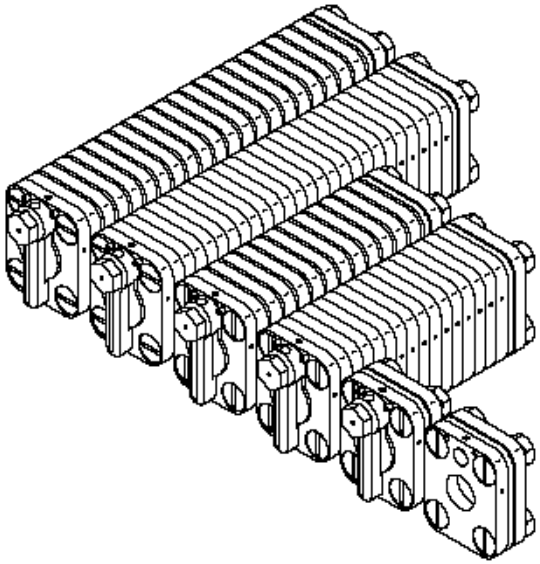
Overview of recent and upcoming DiMES and MiMES experiments in DIII-D

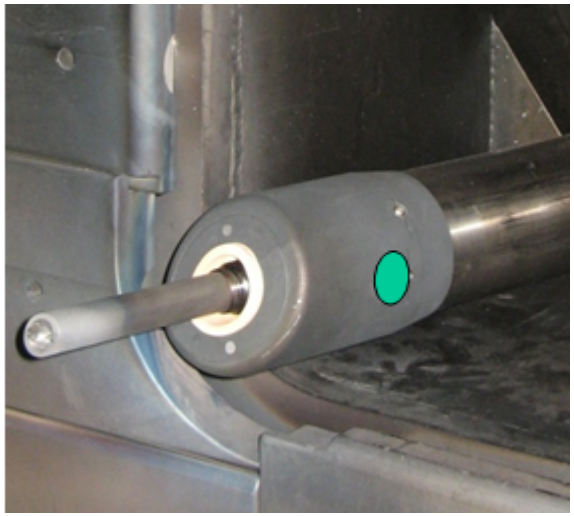
Dmitry Rudakov (UCSD)
for the DiMES Team and Collaborators





Presented at the
PFC Meeting
Oak Ridge TN
August 9-12, 2011





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UCSD

DiMES and MiMES Team and Collaborators

D. Rudakov, R. Moyer	UCSD
C. Wong, N. Brooks, A. Leonard	GA
D. Buchenauer, D. Donovan, J. Whaley	SNL-Livermore
W. Wampler, J. Watkins	SNL-Albuquerque
J. Brooks	Purdue
M. Fenstermacher, C. Lasnier	LLNL
A. Litnovsky, M. Matveeva, O. Schmitz	Forschungszentrum Jülich
P. Stangeby, D. Elder	University of Toronto
A. McLean, Z. Unterberg	ORNL
A. Okamoto	Tohoku University
S. Ratynskaia, H. Bergsåker, I. Bykov	KTH Stockholm
V. Rohde	IPP Garching

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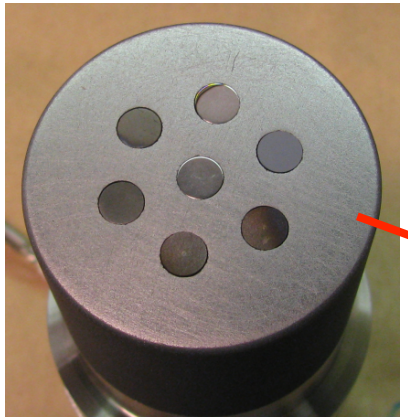
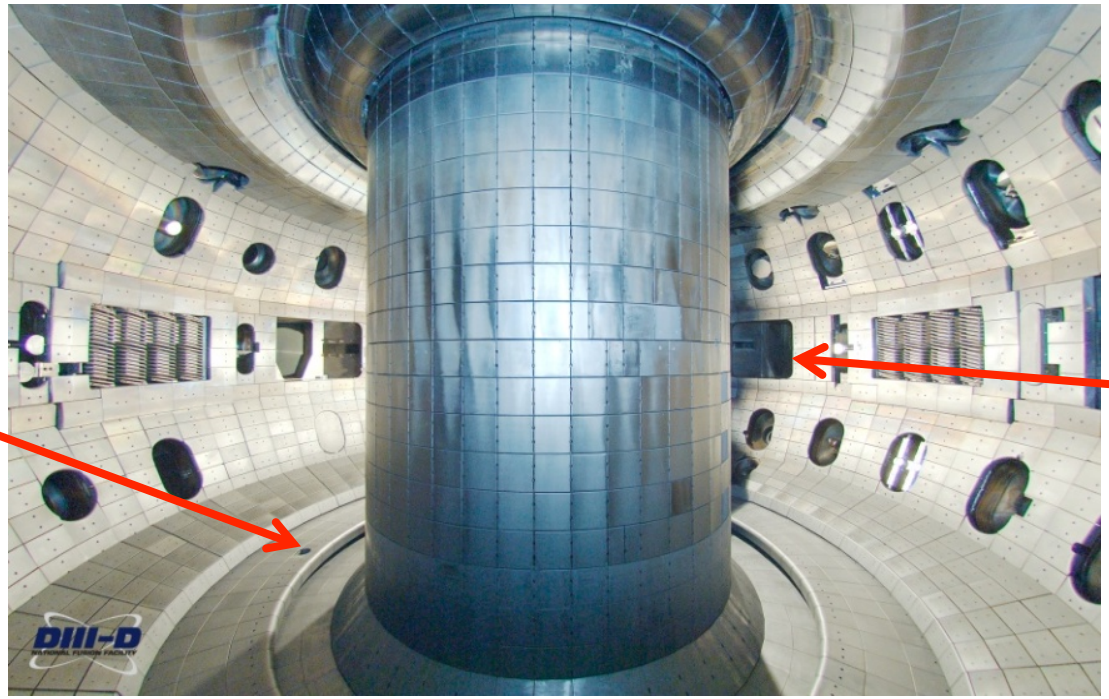
Divertor Material Evaluation System – DiMES
Mid-plane Material Evaluation Sample – MiMES

DiMES





MiMES

- DiMES is a stand-alone system used to insert material samples in the lower divertor of DIII-D
- MiMES is an add-on to the mid-plane reciprocating probe allowing exposure of material and mirror samples
- A minimum exposure in each system is for 1 plasma discharge

Experiments to be covered

This talk

- Gross versus net erosion of high-Z material — Dedicated time
- Dust studies
  - Mobilization of dust from tile gaps
  - ASDEX dust collectors in DIII-D
  - Dust capture with aerogel in MiMES
- First mirror studies
  - Deterioration of mirrors from O-bake
  - Advanced duct geometry for mirror protection

Covered by others

- C. Wong: Si-W surface material development
- D. Donovan: Sheath power transmission studies

Gross versus net erosion of high-Z material

- Experiment proposed and led by Peter Stangeby
- Sample exposure completed on August 1 2011
- Only preliminary results are available

- Motivation
  - It is expected that net erosion of high-Z materials (W, Mo, etc.) should be greatly reduced compared to gross erosion due to prompt re-deposition
  - Experimental indications are inconsistent
  - Analysis of C-Mod tiles shows much higher net erosion than expected from WBC modeling

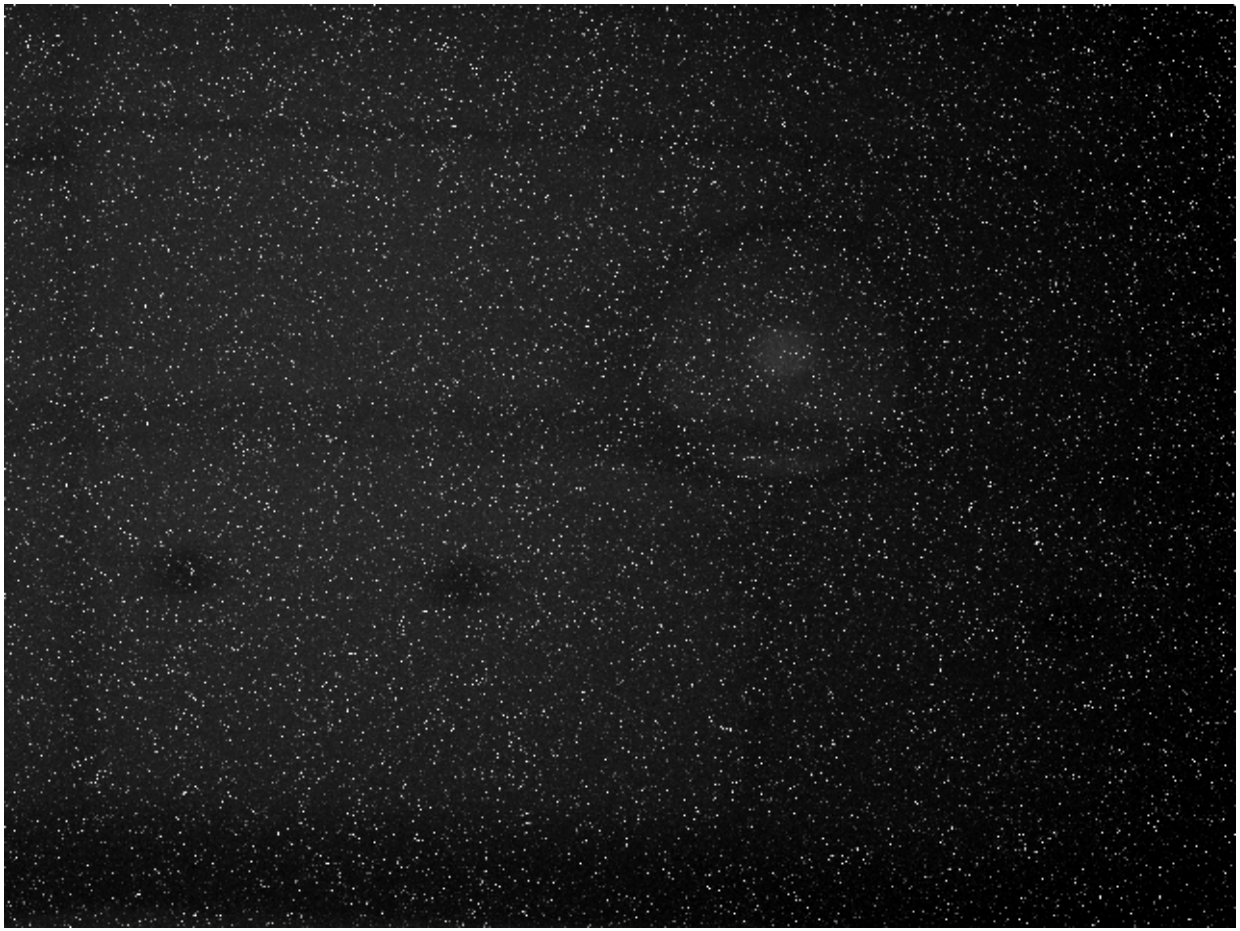
- Experimental approach
  - Expose pre-characterized sample using DiMES under reproducible well-characterized plasma conditions
  - Measure gross erosion spectroscopically, net erosion by IBA
  - Compare with modeling

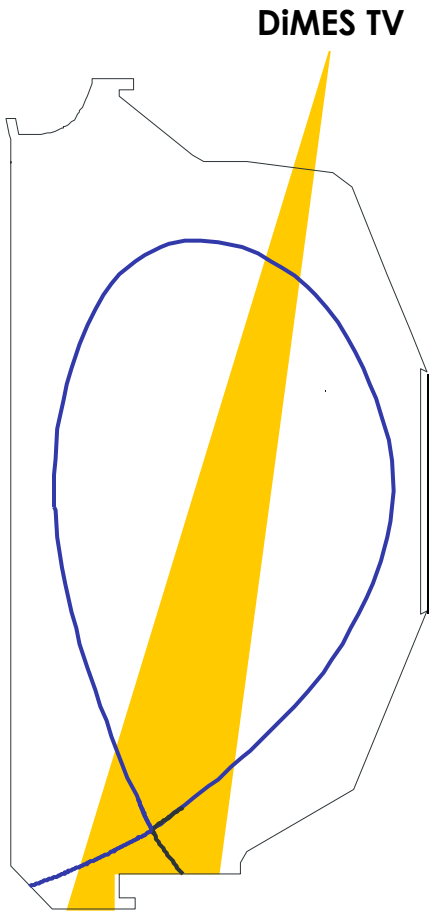
Preparation and execution of the experiment by the DiMES and DIII-D teams

- Mo was picked over W because of better known inverse photon efficiency, S/XB, thus more reliable interpretation of spectroscopic measurements
- A Si disk of 1 cm in diameter was prepared at SNL Livermore (D. Buchenauer)
- Special DiMES holder was fabricated at GA
- The disk was coated by 25 nm of Mo and pre-characterized by IBA (W. Wampler)
- The sample was exposed near the outer strike point of 7 reproducible LSN L-mode discharges using DiMES (operational and diagnostic support by DIII-D team)
- Gross erosion will be estimated from MoI light monitored by a digital CCD camera and MDS spectrometer (N. Brooks and A. McLean)
- Net erosion will be estimated from the change of Mo film thickness, measured by IBA at SNL Albuquerque (W. Wampler)
- IBA will also provide cross-check for prompt re-deposition rate by measuring amount of Mo re-deposited on the graphite DiMES cap next to Mo sample
- Modeling will be performed by D. Elder (OEDGE) and J. Brooks (REDEP/WBC)

MoI light observed by CCD camera

Shot number 145673





R

B_T

DiMES TV, looking down in lower divertor, MoI filter 390 nm, frame rate 5 Hz, integration time 50 ms

Courtesy of N. Brooks

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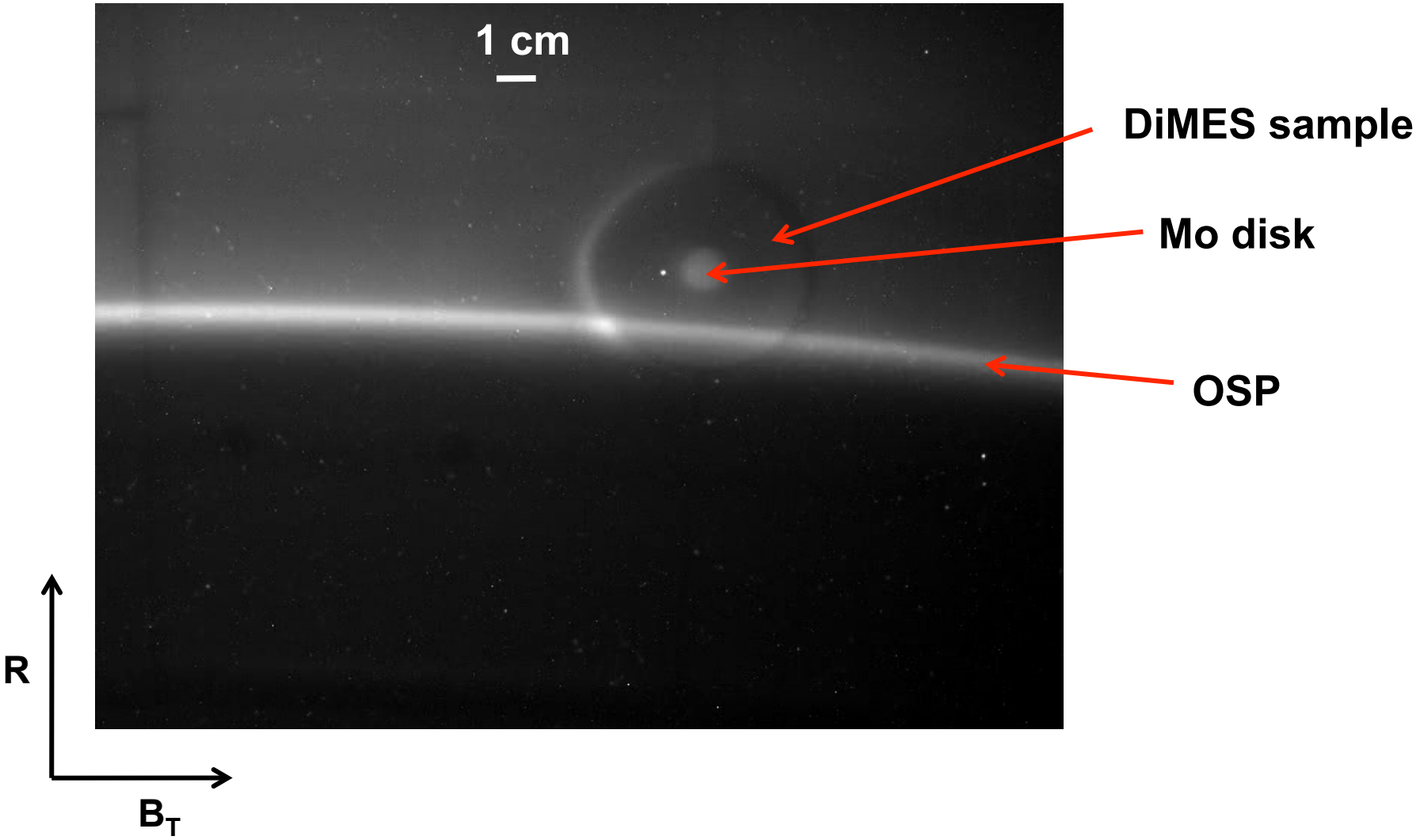
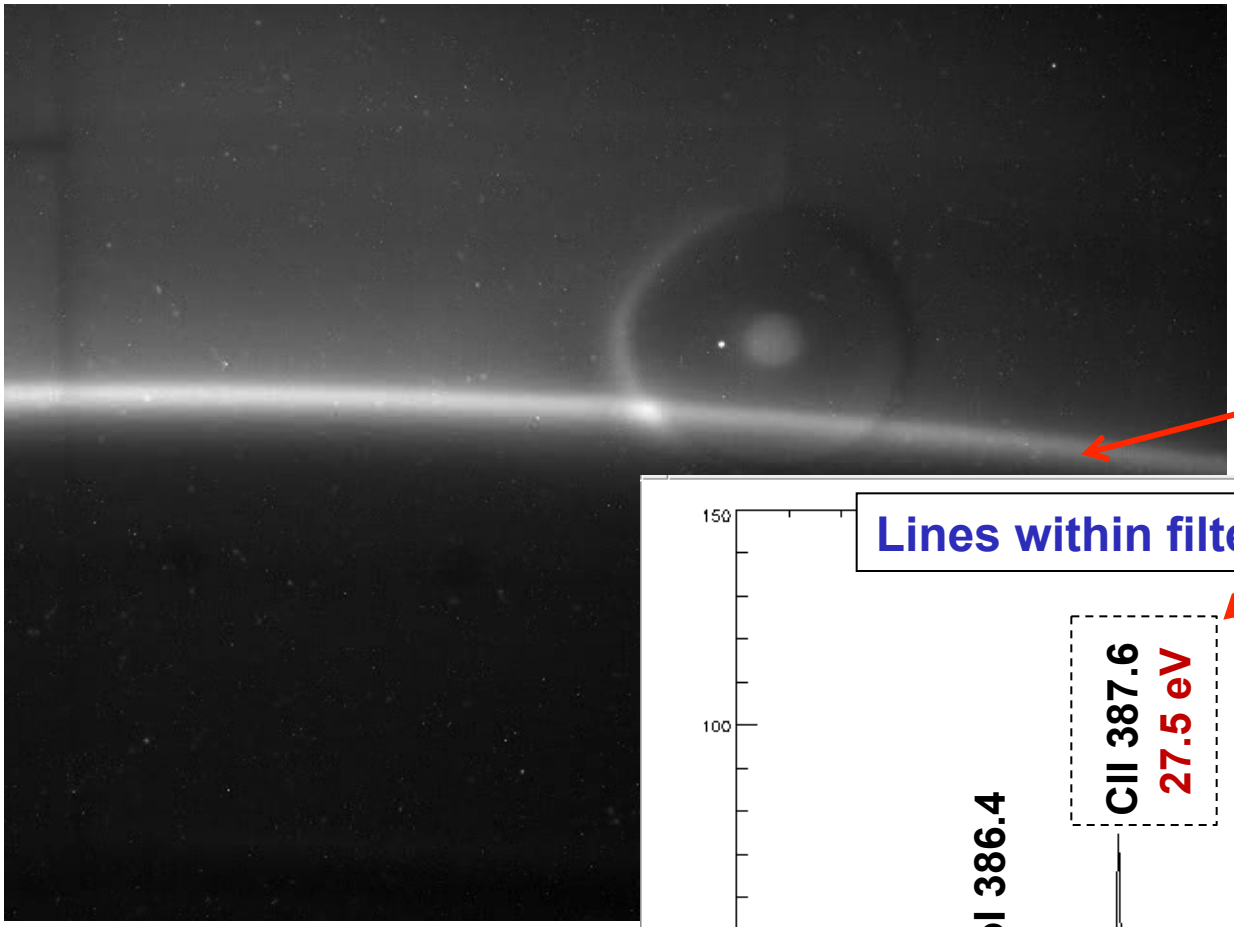
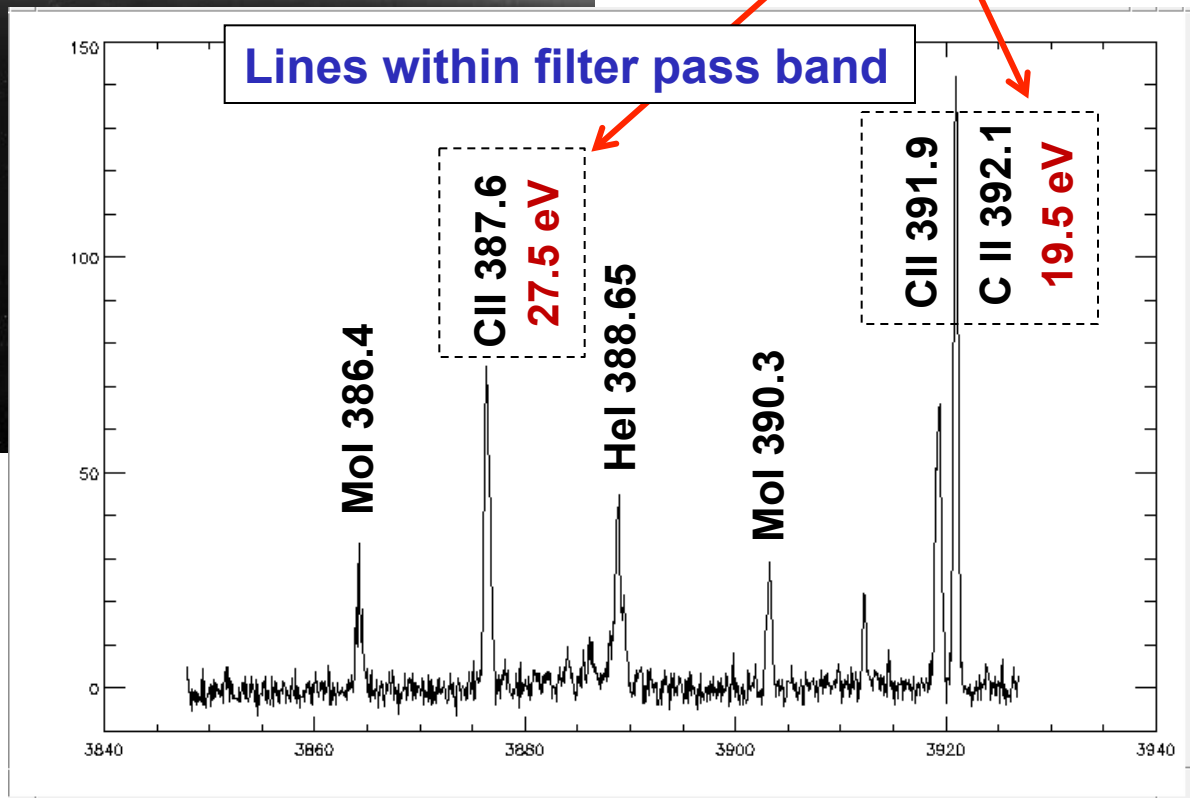
OSP was ~ 1.5 cm inboard of the Mo disk



Measured light at OSP is a combination of CII and HeI emission also in the filter bandwidth



- Due to high excitation energy, CII lines are only visible near OSP



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MDS data courtesy of A. McLean and N. Brooks

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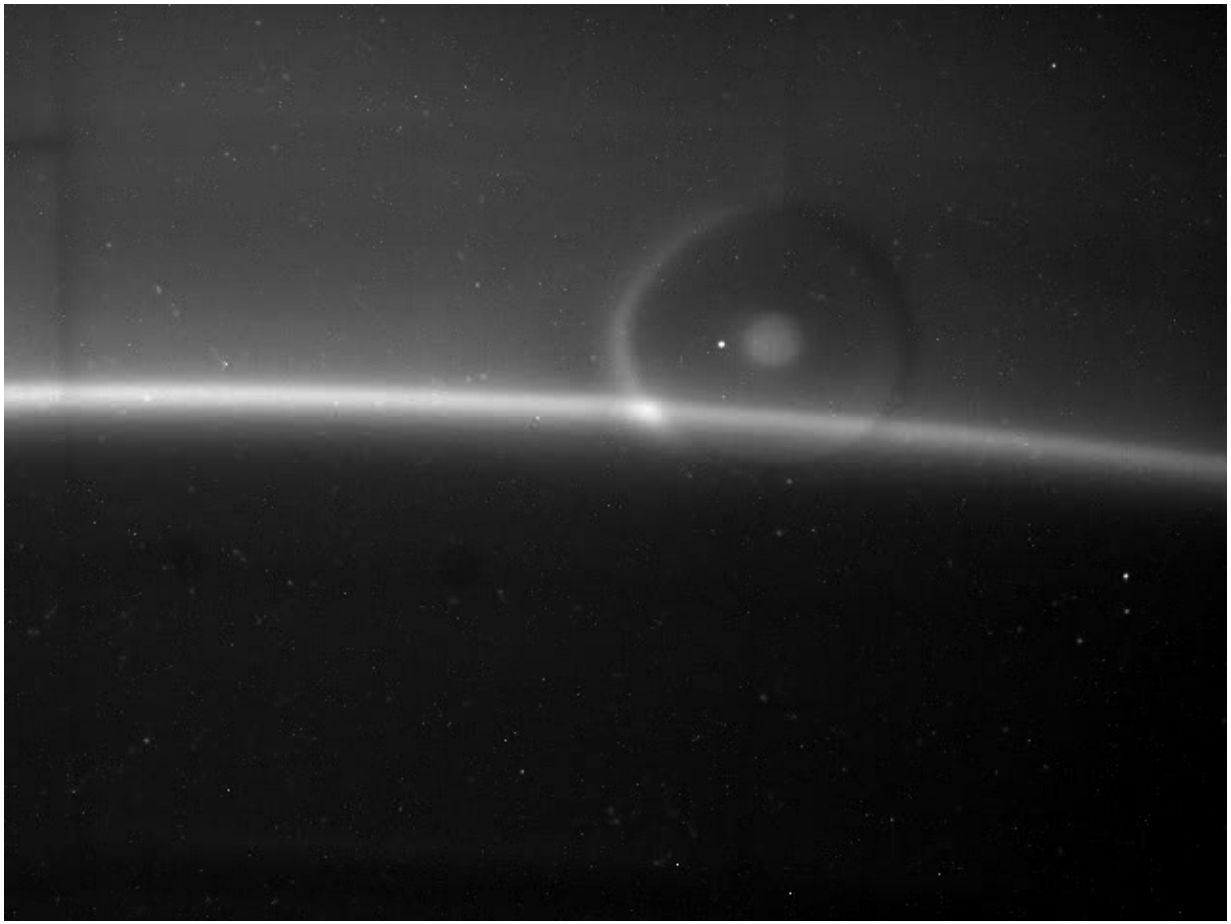
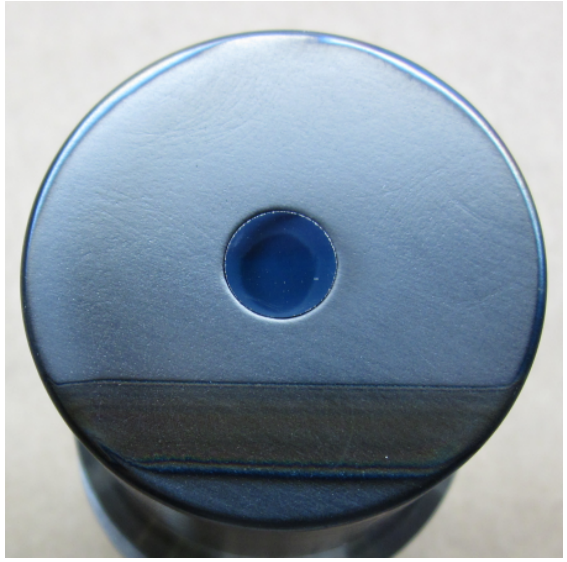
A remarkably well-defined stripe of deposits observed on the sample at OSP location





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B_T

- Deposits will be analyzed by IBA for D and impurity content

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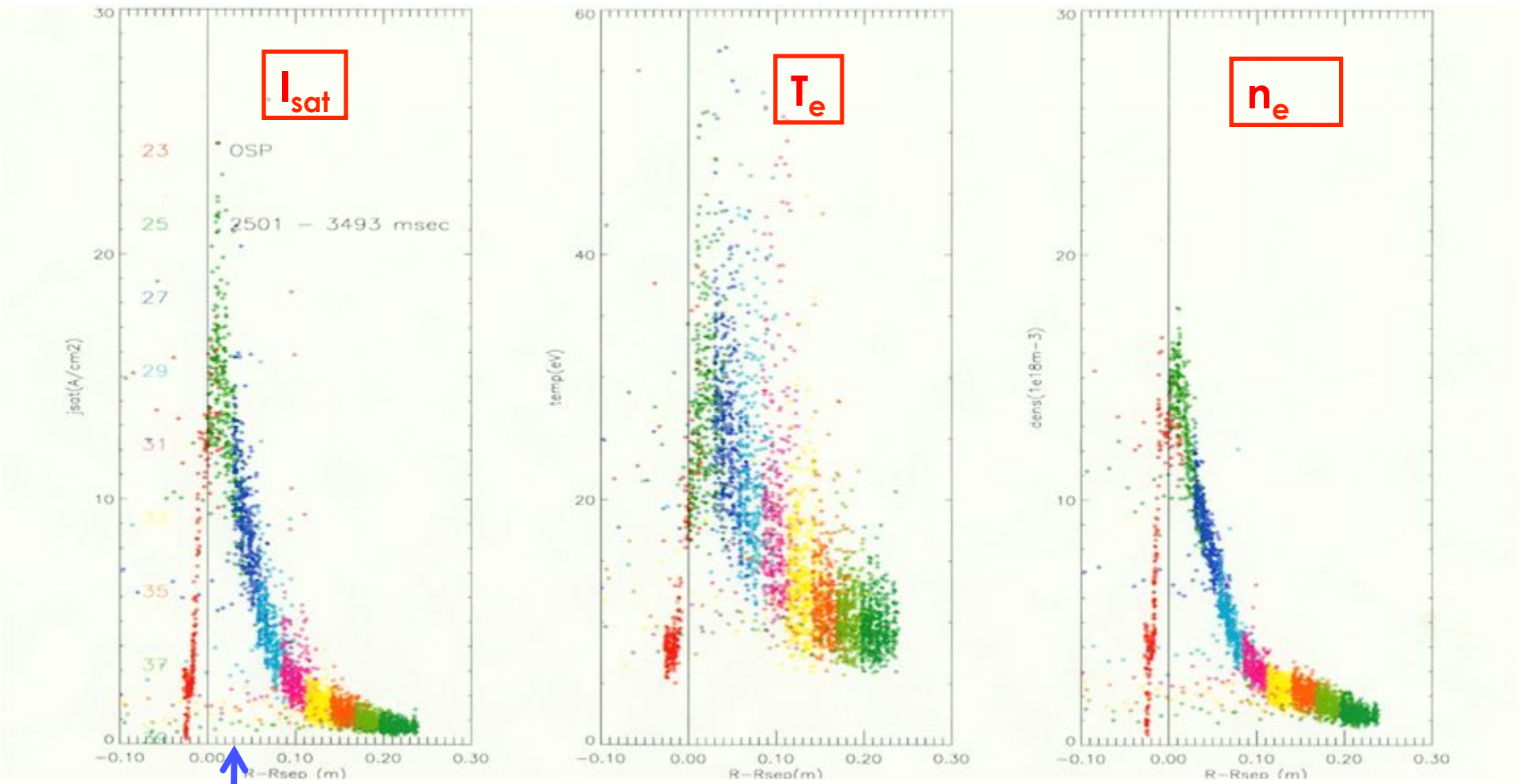
A good set of profiles was collected by divertor probes

- T_e and n_e data will be used as input for the modeling



Dimes
Mo sample

Courtesy of J. Watkins

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Dust studies

Motivation

- Dust accumulation can present a problem in ITER for a number of reasons:
  - C dust: Tritium retention
  - W dust: accumulation of radioactive material
  - Be dust: Hydrogen explosion hazard (in case of simultaneous water and air ingress)

- From operational standpoint, small amounts of W dust (<< 1 g) reaching core plasma can increase W concentration to unacceptable levels

- Dust collections in existing machines allow studies of dust particle chemical composition and morphology, which in turn shed some light on the relative importance of various dust production mechanisms

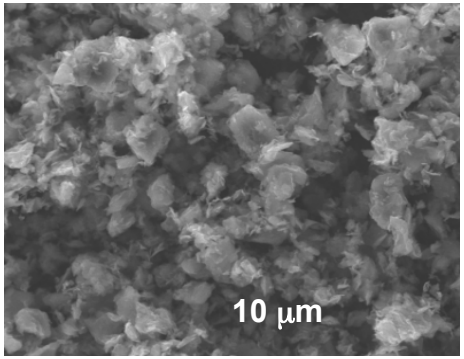
- Injections of pre-characterized dust into tokamak divertor and SOL are performed under ITPA DSOL-21 experiment (D. Rudakov, coordinator) to:
  - Study core penetration efficiency and impact of dust on the core plasma performance
  - Study of dust mobilization from PFCs
  - Benchmark DustT and DTOKS modeling of dust transport and dynamics

Studies of Mobilization of Dust from Tile Gaps

- Is dust fallen in tile gaps permanently retained or can it be re-mobilized by plasma contact?

- A DiMES sample with simulated poloidal and toroidal gaps 0.9 mm wide, 20 mm long and up to 5 mm deep was fabricated to investigate dust mobilization

- First experiment was performed in 2009:
  - ✓ Gaps were filled with flake graphite dust that was pressed in
  - ✓ Sample has been exposed in a few discharges with OSP sweeps
  - ✓ Dust loss from the sample was very small, to depth less than 0.1 mm

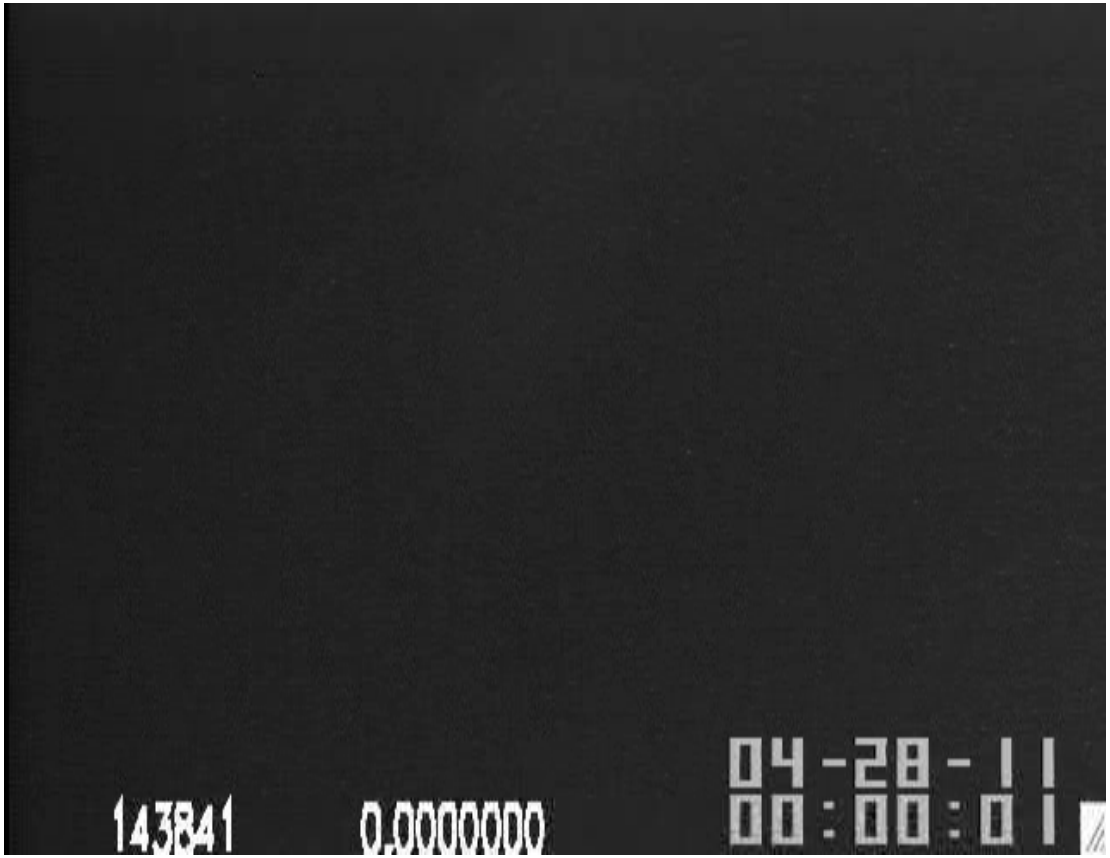


New Experiment Performed in 2011

- New experiment performed in April 2011 during plasma startup:
  - ✓ Flake graphite dust was placed on top of the gaps and the sample was shaken till the dust settled in and completely filled the gaps
  - ✓ Sample has been exposed in H-mode LSN discharge with OSP sweep
  - ✓ Dust ejection in a few bursts starting 300 ms into the discharge was observed by a tangential divertor TV

Dust Mobilization from Tile Gap Observed Directly

- New experiment performed in April 2011 during plasma startup:
  - ✓ Flake graphite dust was placed on top of the gaps and the sample was shaken till the dust settled in and completely filled the gaps
  - ✓ Sample has been exposed in H-mode LSN discharge with OSP sweep
  - ✓ Dust ejection in a few bursts starting 300 ms into the discharge was observed by a tangential divertor TV



Courtesy of M. Fenstermacher

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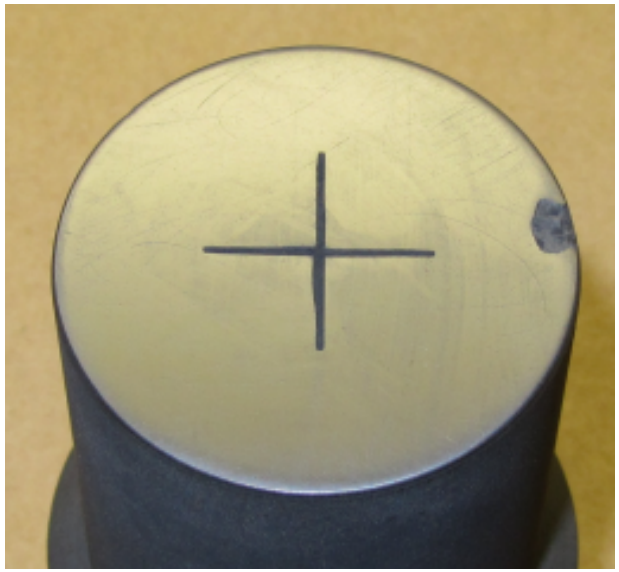
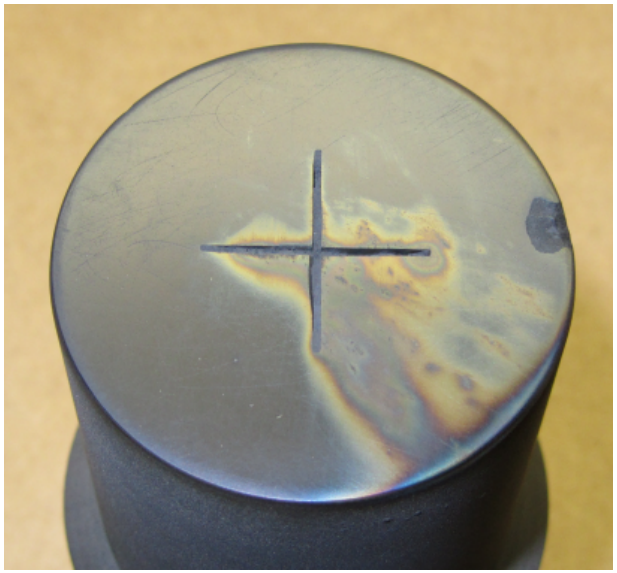
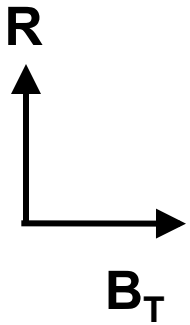
Dust Loss from the Gap Was to a Depth of 0.5 – 1 mm

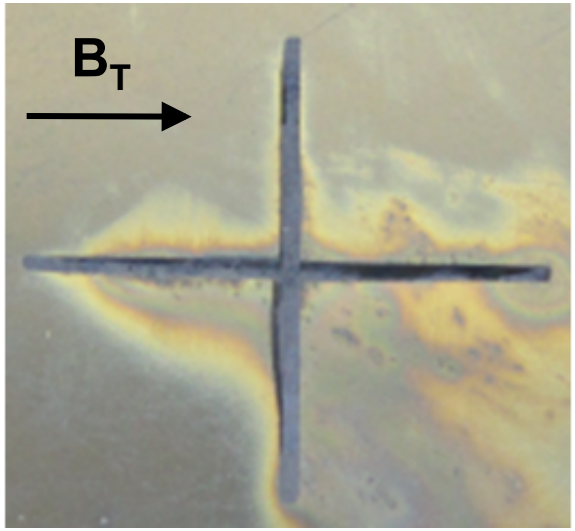
- Upon the sample extraction, dust loss to a depth of 0.5 – 1 mm was observed
- This is consistent with the earlier NSTX results (C. Skinner)

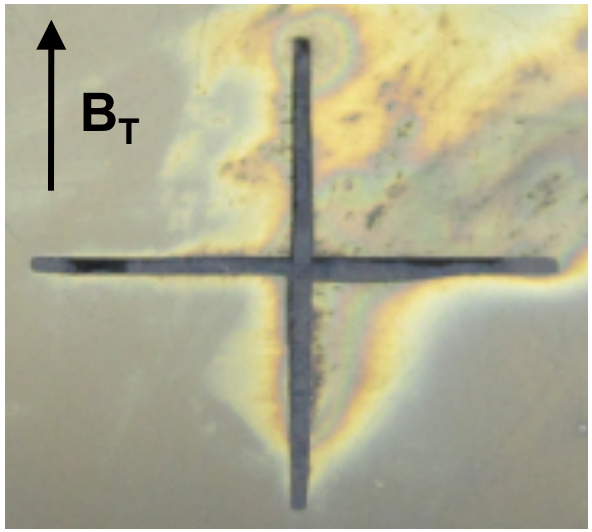






Amount of the dust lost
~ 3 mm^3 or ~ 1 mg





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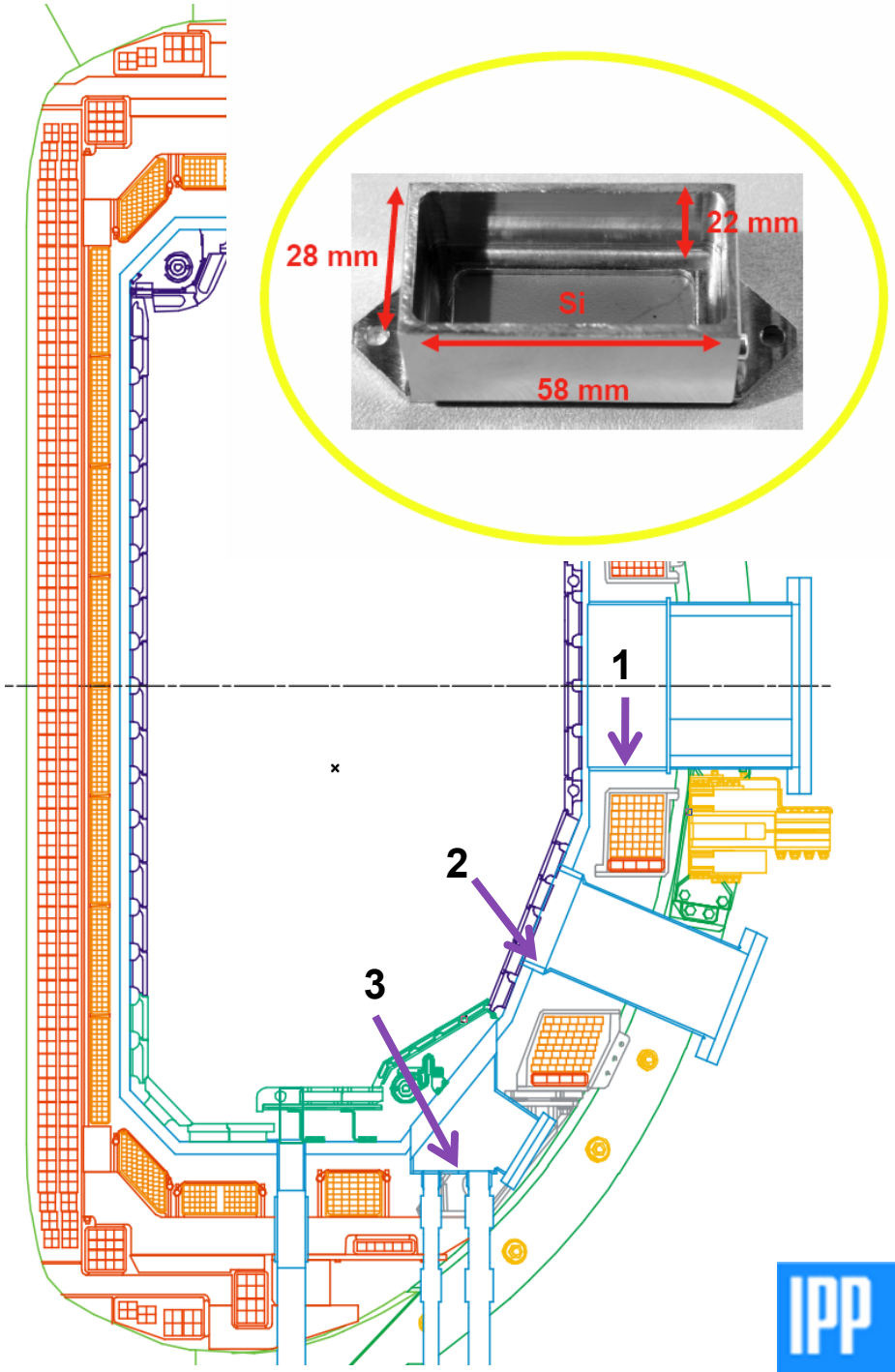
ASDEX dust collectors in DIII-D

- Filtered vacuum technique most often used for dust collection in tokamaks has shortcomings:
  - Small particles pass through the filter
  - If mechanical contact of nozzle with surface occurs, it results in peeling of flakes, etc.
- Dust collectors developed at ASDEX are good addition to filtered vacuum, their wider use recommended by ITPA DSOL group, installation proposed for LHD, DIII-D, JET, TS
- 3 dust collectors supplied by IPP were installed in DIII-D for 2011 campaign
- Collected dust will be analyzed at IPP



Collaboration with V. Rohde

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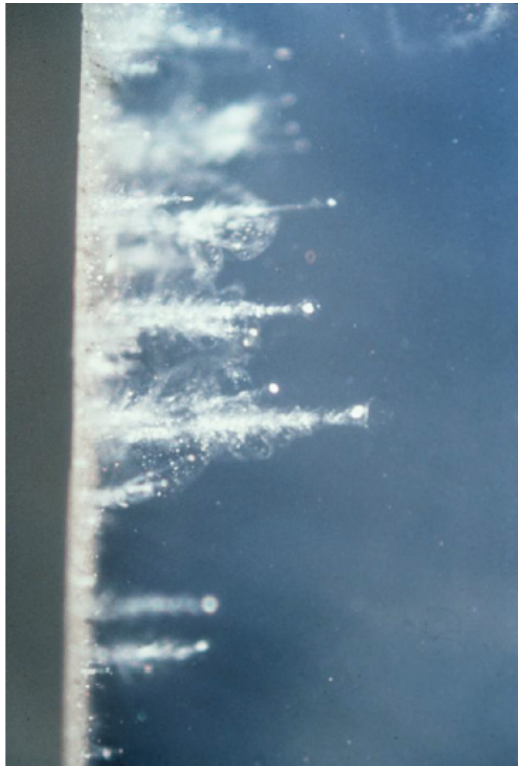
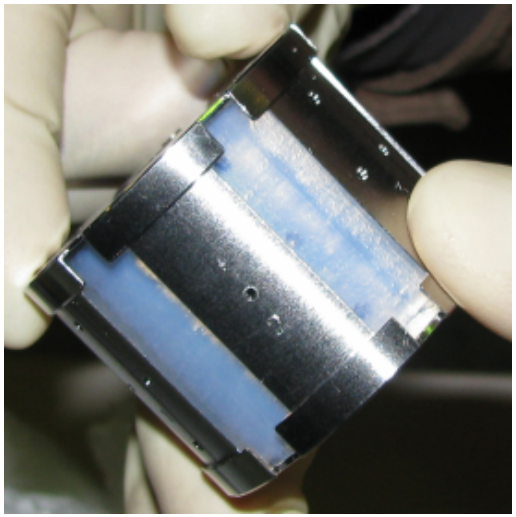
IPP

New Dust Collection Technique: Aerogel

- Highly porous, very low density material
- Used in NASA Stardust mission to collect comet dust
- Allows capture of dust particles without destroying them
- From the penetration depth particle velocity can be derived
- Tests of aerogel performed in HT-7, TEXTOR and EXTRAP-T2 with encouraging results
- Most recent experiments performed in TEXTOR in May 2011

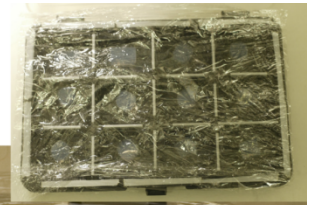


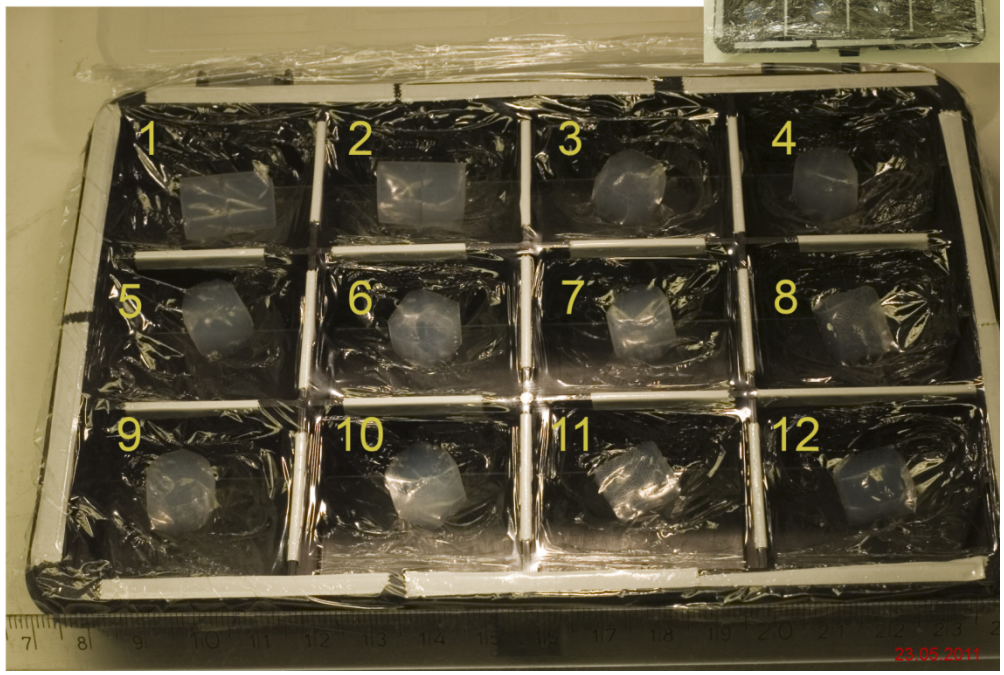


Aerogel tests in DIII-D using MiMES

- **Aerogel samples for DIII-D prepared by I. Bykov (KTH)**

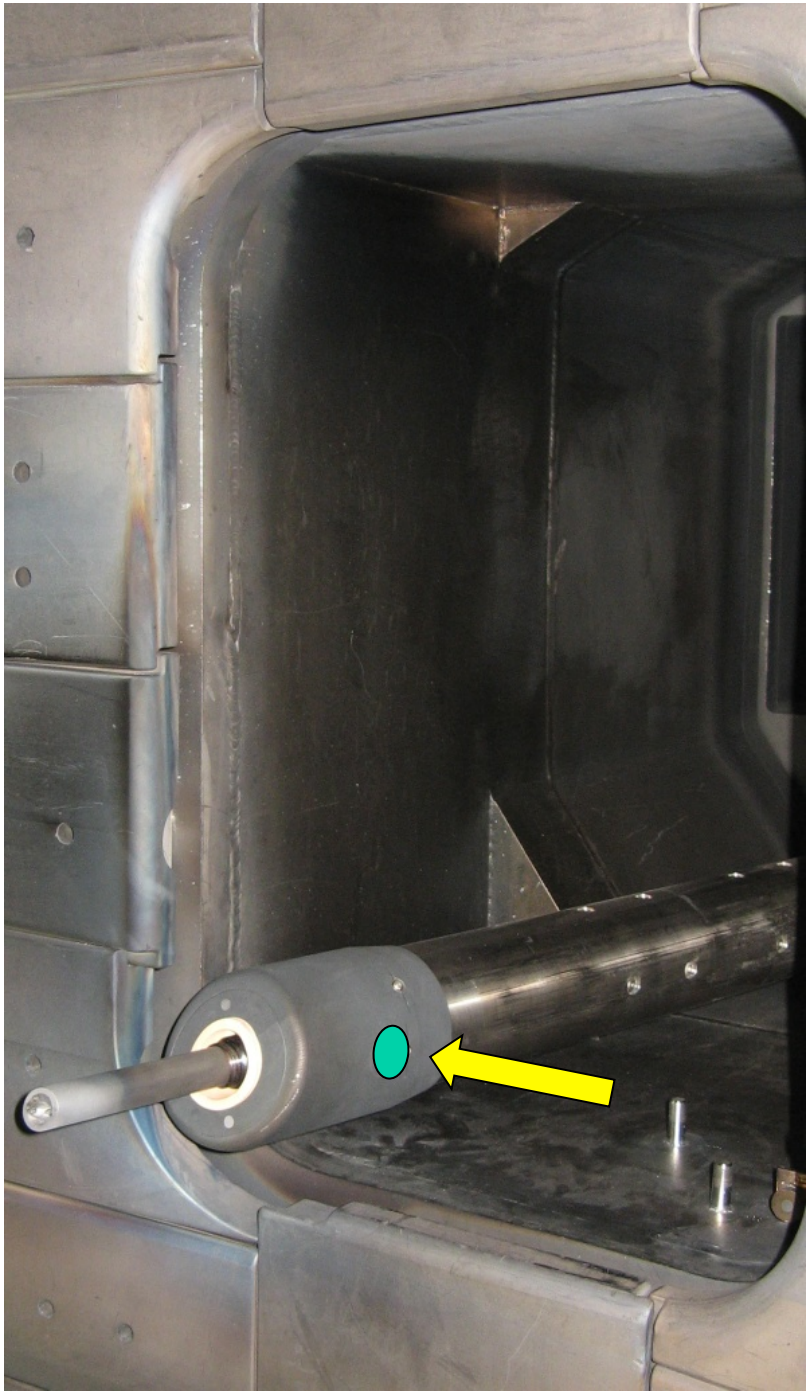
• 2 cracked cylindrical samples (for best clean surfaces): 1,2
• 3 rectangular samples: 8,11,12
• other samples are cylindrical, approx. 10mm thick





- **Samples will be installed in the side mirror slot of MiMES**

- **Experiments are planned for September – October 2011**



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Collaboration with S. Ratynskaia

First mirror studies

First mirror tests – an ongoing collaboration with FZJ

- Deterioration of first mirrors caused by erosion and deposition is a large concern for ITER
- Various deposition mitigation techniques are being investigated
- There is an ongoing collaboration project since 2005 between DIII-D/DiMES and Forschungszentrum Jülich (A. Litnovsky) on first mirror studies
- A number of experiments have been conducted resulting in a few publications
  - D. Rudakov et al., Rev. Sci. Instrum. 77 (2006) 10F126
  - A. Litnovsky et al., J. Nucl. Mater. 363–365 (2007) 1395–1402
  - D. Rudakov et al., Phys. Scr. T128 (2007) 29–34
  - A. Litnovsky et al., Fusion Eng. Des. 83 (2008) 79–89
- 8 mirrors (6 Mo and 2 Cu) were exposed during O-bake campaign in DIII-D in 2010; preliminary results were reported at the meeting at UCLA last year
- Analysis of the exposed mirrors has been performed by FZJ
- Reflectivity of all mirrors deteriorated significantly below 500 nm
  10 – 50% decrease for Mo, up to 90% decrease for Cu
- Abstract by A. Litnovsky et al was accepted for invited talk at ICFRM-15

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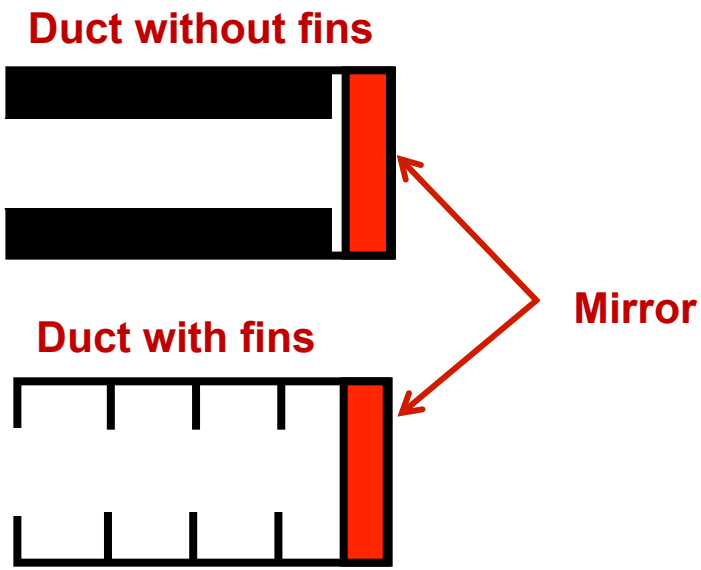
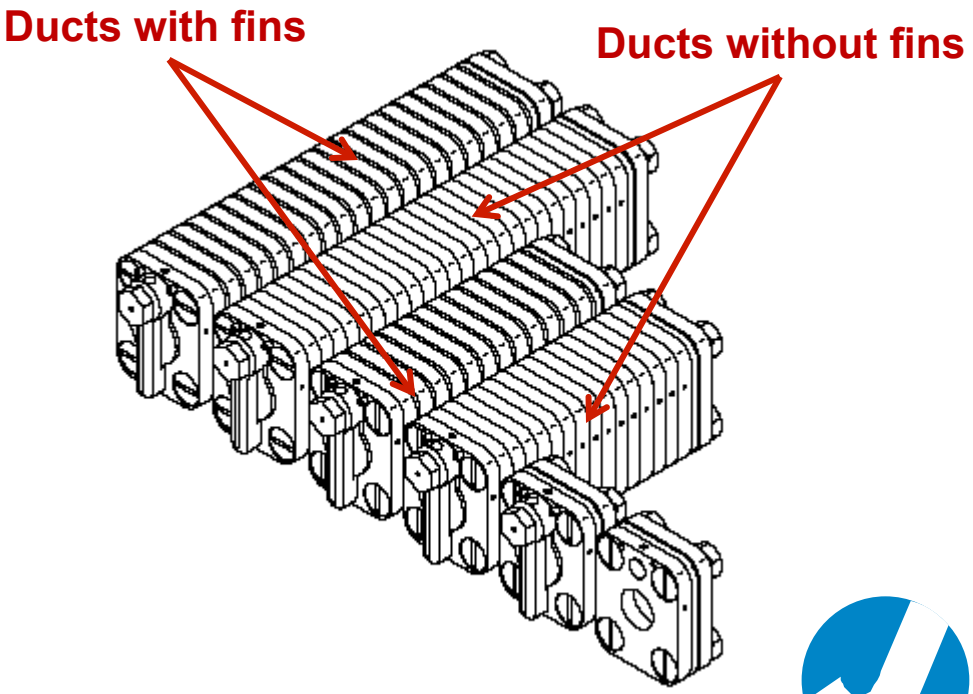
Mirrors with varying duct geometry in DIII-D

- Modeling results show that ducts with ribs or "fins" in front of a mirror can significantly reduce deposition rates compared to smooth ducts of similar length and apperure
- 6 similar Mo mirrors will be exposed in DIII-D with ducts of different length with and without fins
- 5 mirrors will have shutters activated by the B-field to prevent any effect from the glow discharge
- Mirrors and ducts will be pre-assembled at FZJ and delivered to DIII-D for exposure in a mid-plane port during FY 2012 campaign
- The results will be used to benchmark modeling





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Thanks for your attention!