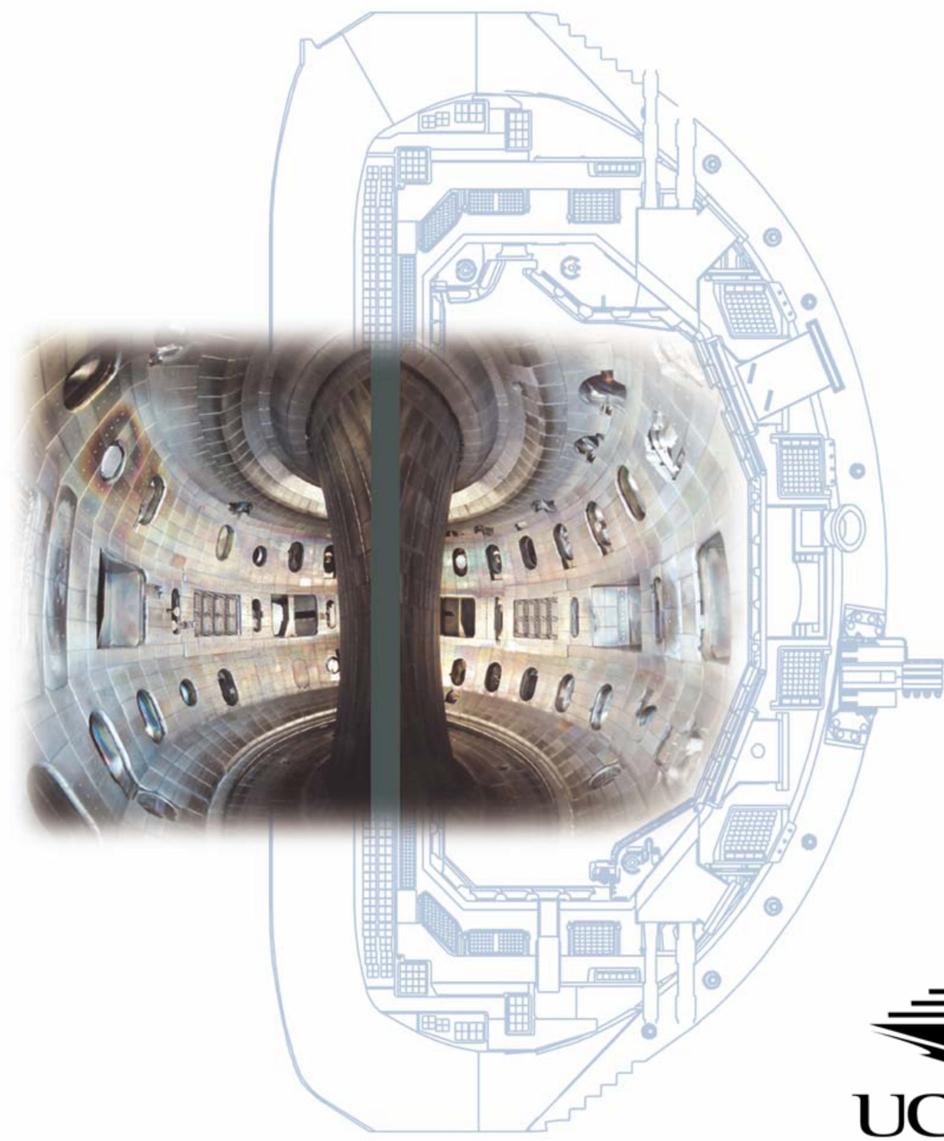
Effect of the Surface Temperature on Net Carbon Deposition and Deuterium Co-deposition in the DIII-D Divertor

Presented by
Dmitry Rudakov (UCSD)
for the DiMES Team
and Collaborators



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UCSD

Full list of co-authors should look like this

An international multi-institutional team

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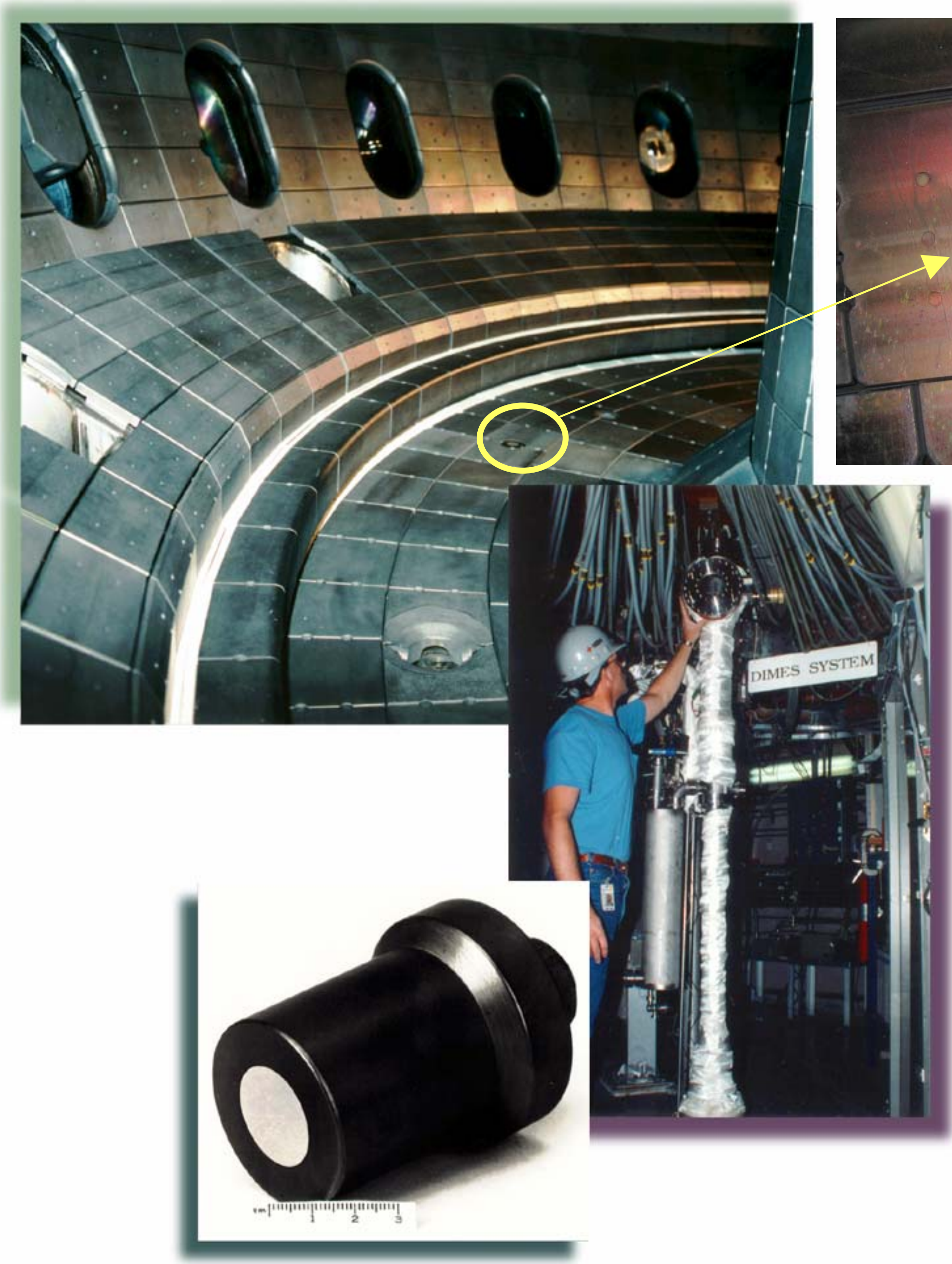
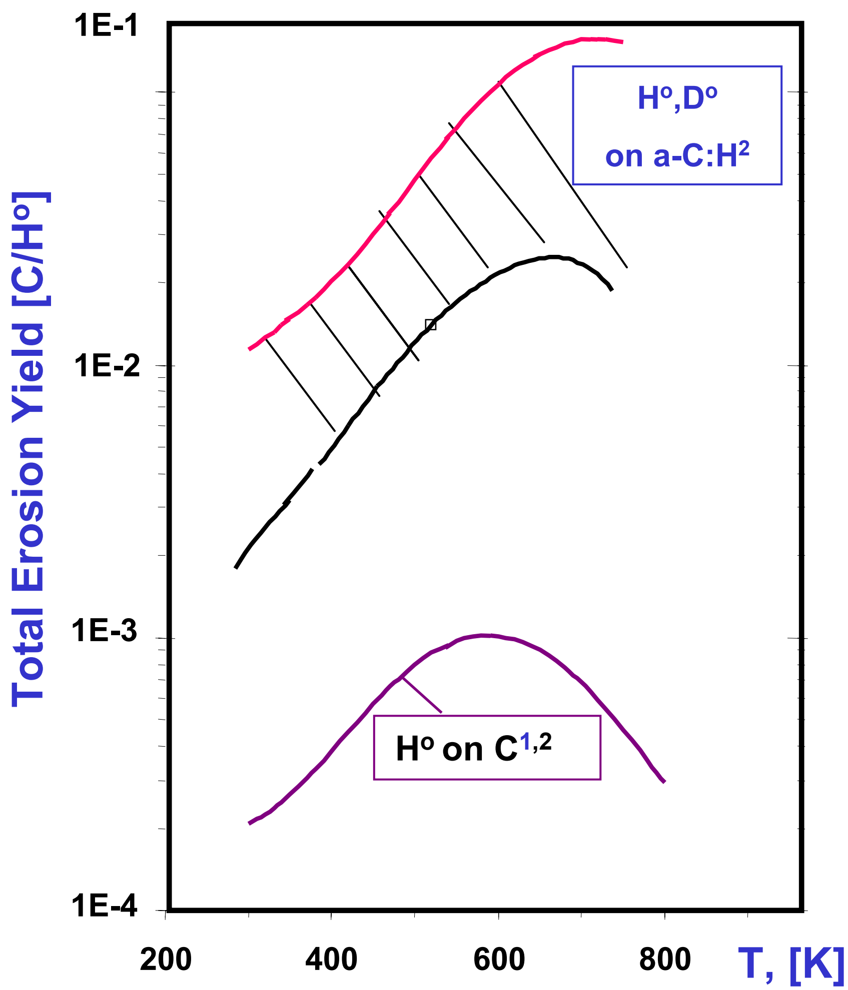
Divertor Material Evaluation System - DiMES



- DiMES system is used to insert material samples in the lower divertor of DIII-D for erosion and deposition studies
- A newly developed *in situ* sample heating capability allows us to study the temperature dependence of erosion/deposition

Why study temperature dependence of erosion/deposition? At high surface temperatures chemical erosion is increased



1. J.W. Davis et al, JNM 155-157(1988), 234;
2. E. Vietzke et al. Fus. Technol. 15 (1989), 108.

Erosion by atomic H and D (0.2 eV)

- Chemical erosion rate of hydrocarbon films increases with surface temperature peaking at around 400°C
- By heating the surface it may be possible to reduce/prevent deposition of hydro-carbon films
- We have recently obtained experimental evidence of deposition rate reduction at elevated temperature in DIII-D divertor
- Two separate experiments will be reviewed in this talk

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Studies of C deposition and D co-deposition in a simulated tile gap - Tile Gap DiMES

Originally proposed by Wolfgang Jacob
Max-Planck-Institut fuer Plasmaphysik, Germany

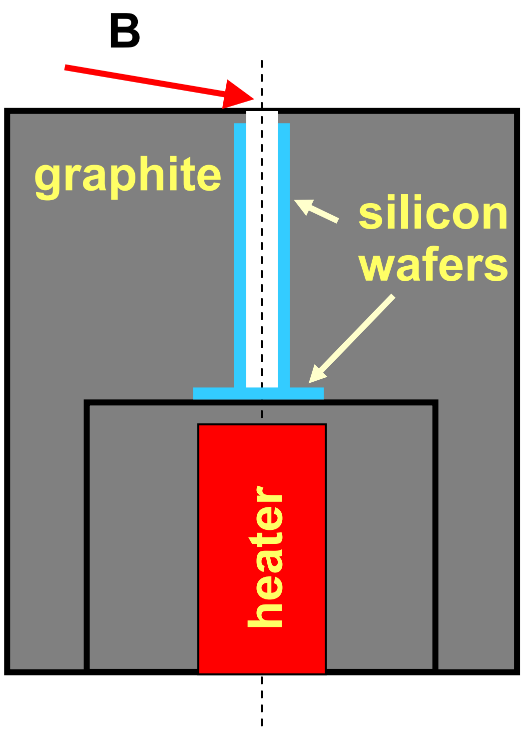
Motivation

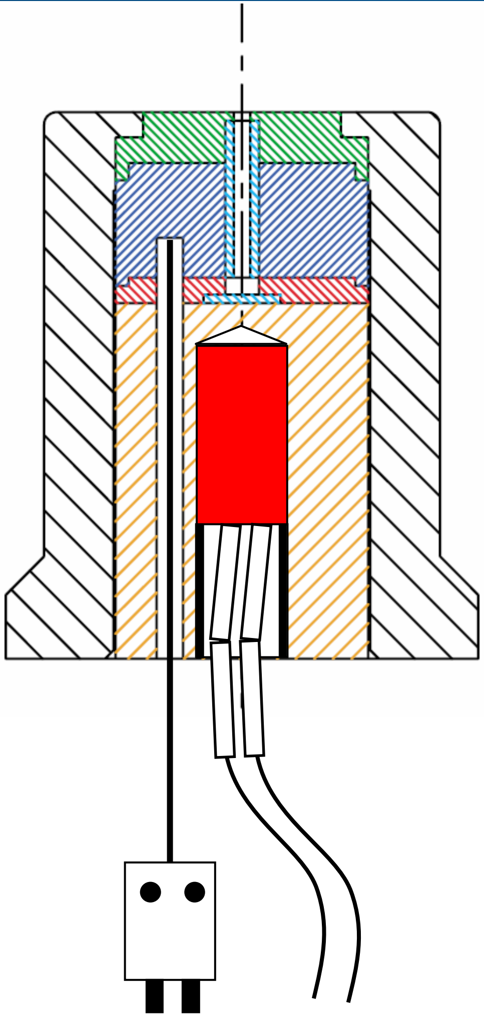
- Tritium co-deposition/retention is one of the most critical issues for ITER
- High-priority ITPA topic
- One of the most troublesome carbon deposition regions for trapping tritium are the narrow tile gaps since such regions are not accessible to many of the proposed T-recovery methods
- In DIII-D co-deposition of deuterium (as a proxy for tritium) can be studied in a simulated tile gap using DiMES
- Altering the tile temperature may affect C deposition and D co-deposition rates

Tile Gap DiMES experimental concept and design

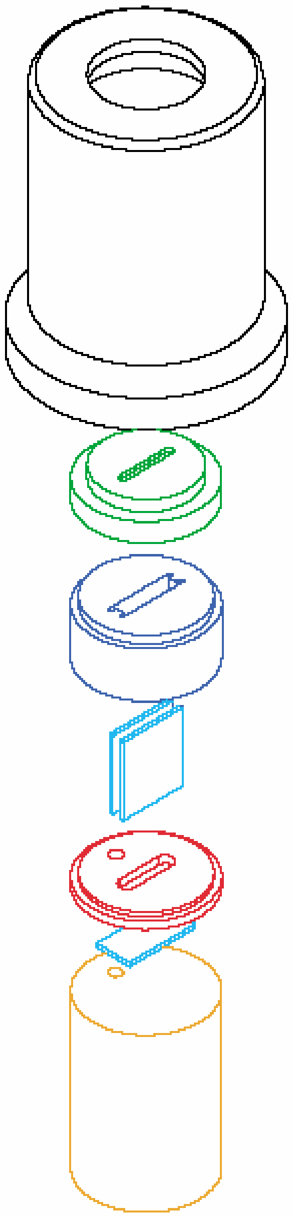
Concept features:

- radially oriented gap
- deposition on the silicon wafers
- defined geometry for modeling of the deposition profile

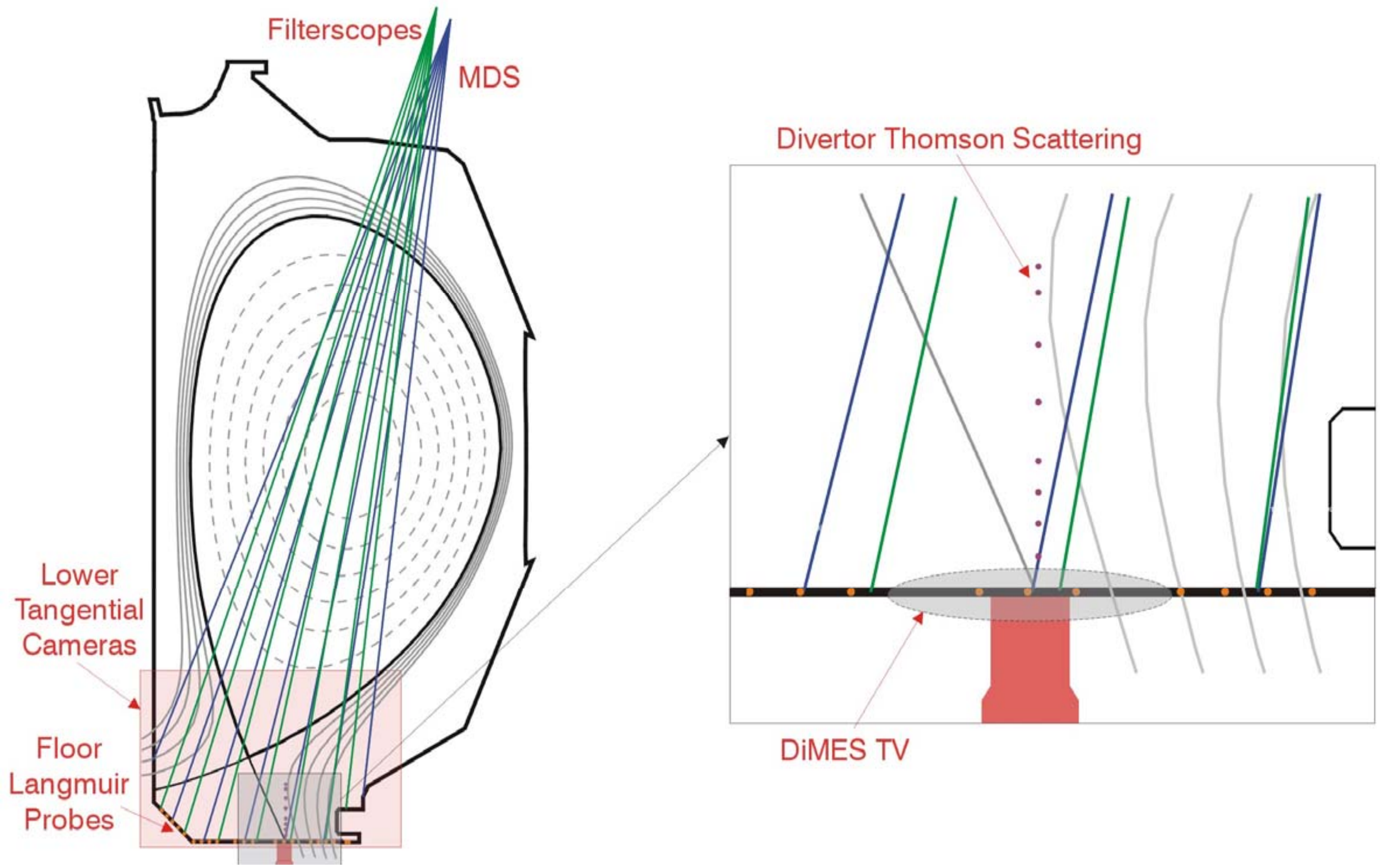




Built in heater and thermocouple for *in situ* temperature control



Two exposures at different temperatures were performed



- Lower Single Null Simple-As-Possible Plasma (SAPP) shape
- DiMES located near the detached Outer Strike Point (OSP)
- Two exposures were performed, first at ~ 30º C, second at 200º C
- Each exposure was to 9 highly reproducible high-density L mode shots for a total exposure time of about 32 seconds

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Non-heated versus heated exposures: plasma-facing surface

Non-heated

- There were visible signs of plasma contact on the sample face upon removal, most likely deposits
- No net erosion/deposition measurements were available

Heated

- No visible signs of plasma contact on the sample face upon removal
- A graphite button with implanted Si marker was built in the sample face to measure net erosion/deposition on the plasma-facing surface

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A high erosion rate was measured on the heated sample

- Ion Beam Analysis (IBA) at SNL Albuquerque has shown a total net erosion of about 90 nm on the depth marked button from heated exposure

- This corresponds to a net erosion rate of ~ 3 nm/sec – rather high!

- We did not have erosion/deposition measurements on the non-heated sample, but it looked like there was some net deposition

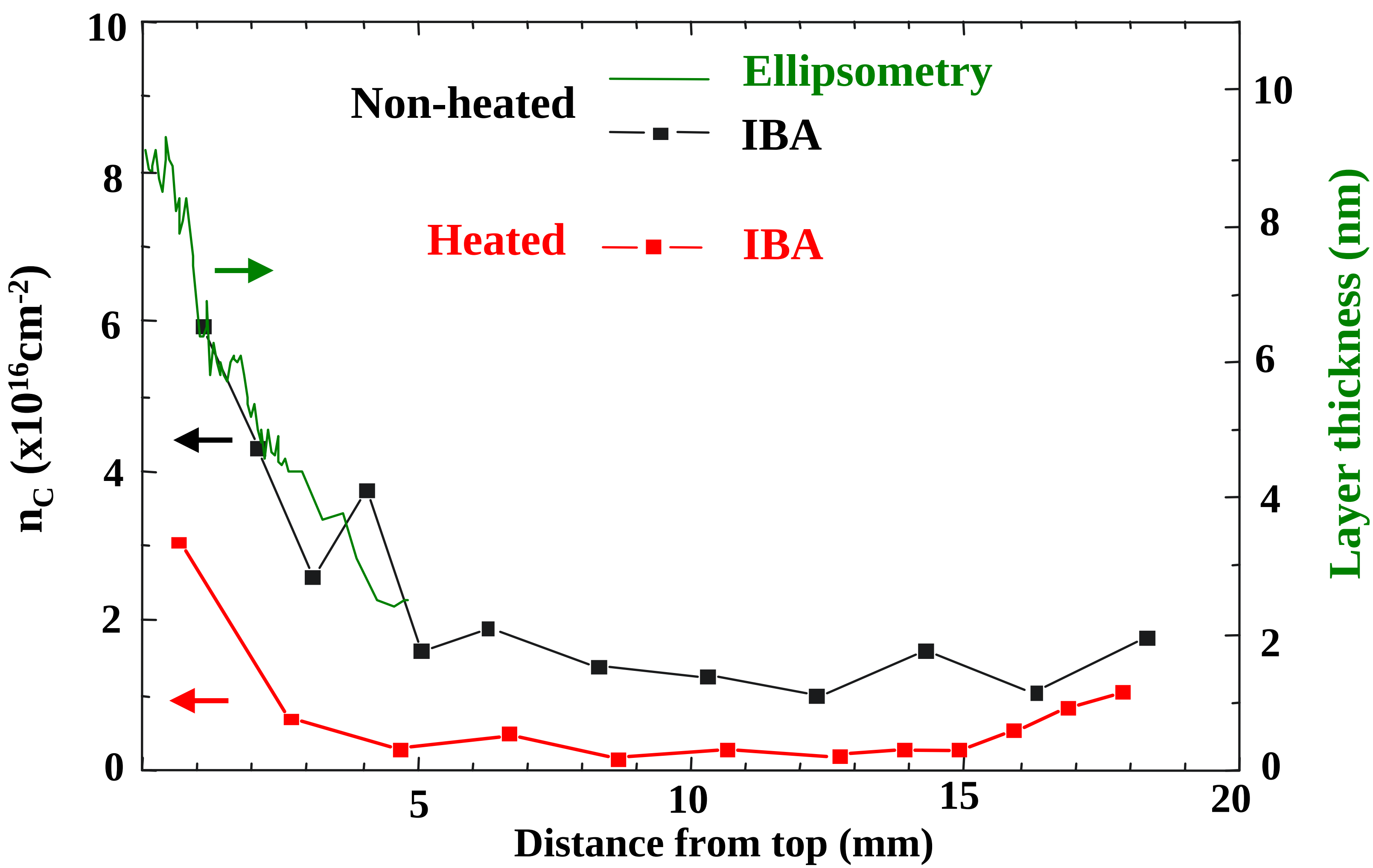
- No net erosion was observed in other experiments with detached divertor:

  - A depth-marked DiMES sample exposed later to 7 comparable high-density SAPP L-mode discharges (but with OSP sweeps) showed no measurable erosion

  - Previous DiMES experiments in detached H-mode showed net deposition around OSP and in the PF zone [Whyte et al., Nucl. Fusion 41 (2001) 1243]

The observed erosion must be due to the elevated temperature

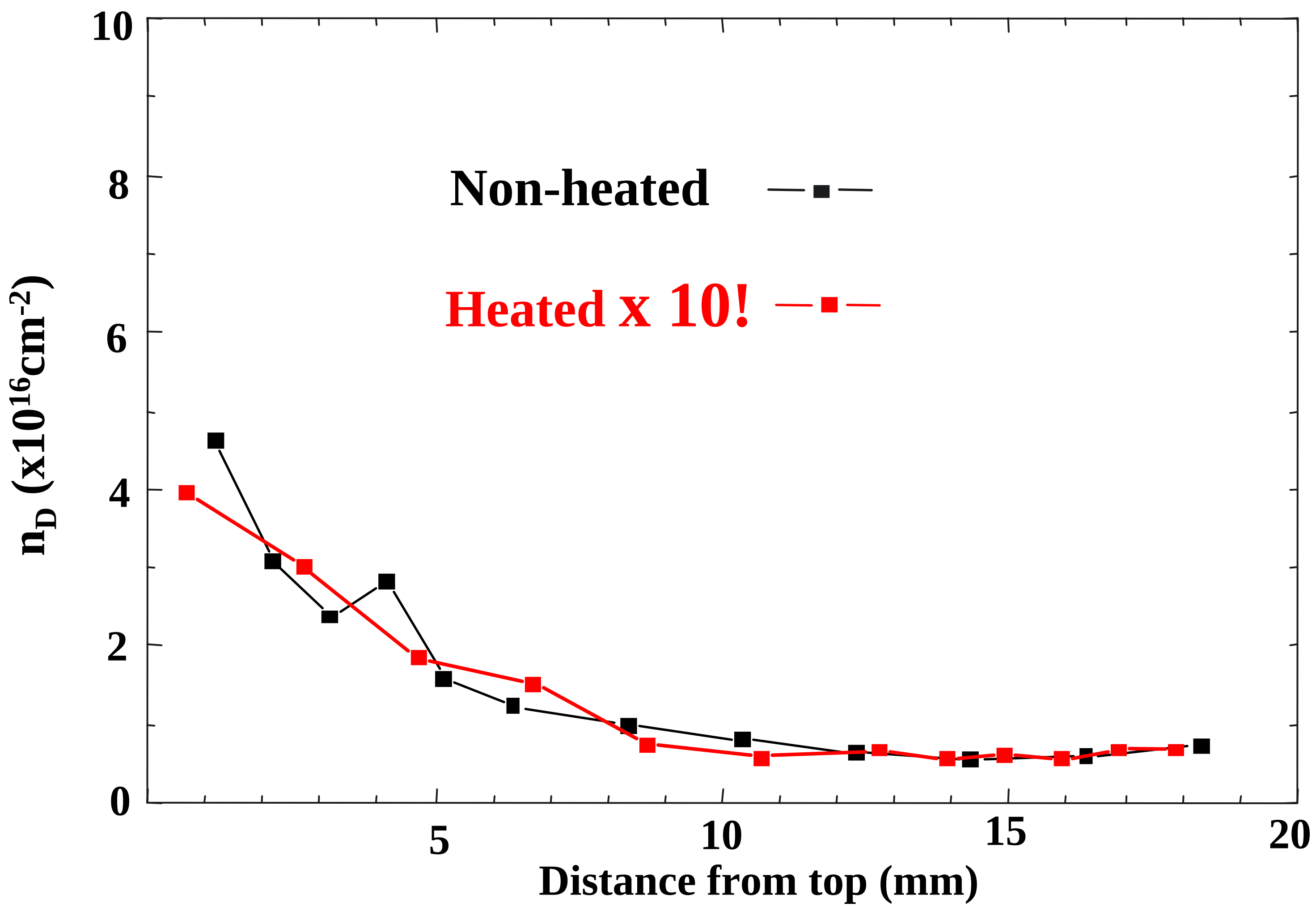
Carbon deposition inside the gap was a factor of 2 - 4 lower in the heated exposure



- C deposition inside the gap was ~ 2 - 4 times lower in the heated exposure
- Some of the carbon in heated exposure may have been absorbed into the wafers to form silicon carbide

IBA data courtesy of K. Krieger, Ellipsometry courtesy of W. Jacob

D co-deposition inside the gap was an order of magnitude lower in the heated exposure



Potentially a good news for ITER:

it may be possible to control WHERE the T co-deposition would occur

IBA data courtesy of K. Krieger

Tests of ITER-relevant diagnostic mirrors in a tokamak divertor - Mirror DiMES

Originally proposed by Andrey Litnovsky
Forschungszentrum Jülich, Germany

Motivation

- Optical mirrors are foreseen in ITER for many diagnostics, and will be used in infrared, visible and ultraviolet wavelength ranges
- High-priority ITPA topic
- Mirrors in the ITER divertor will likely suffer from deposition, and dedicated experiments in tokamak divertors are urgently needed
- Using DiMES, we had a chance to perform first ever tests of ITER-relevant mirrors in a tokamak divertor under well-diagnosed plasma conditions

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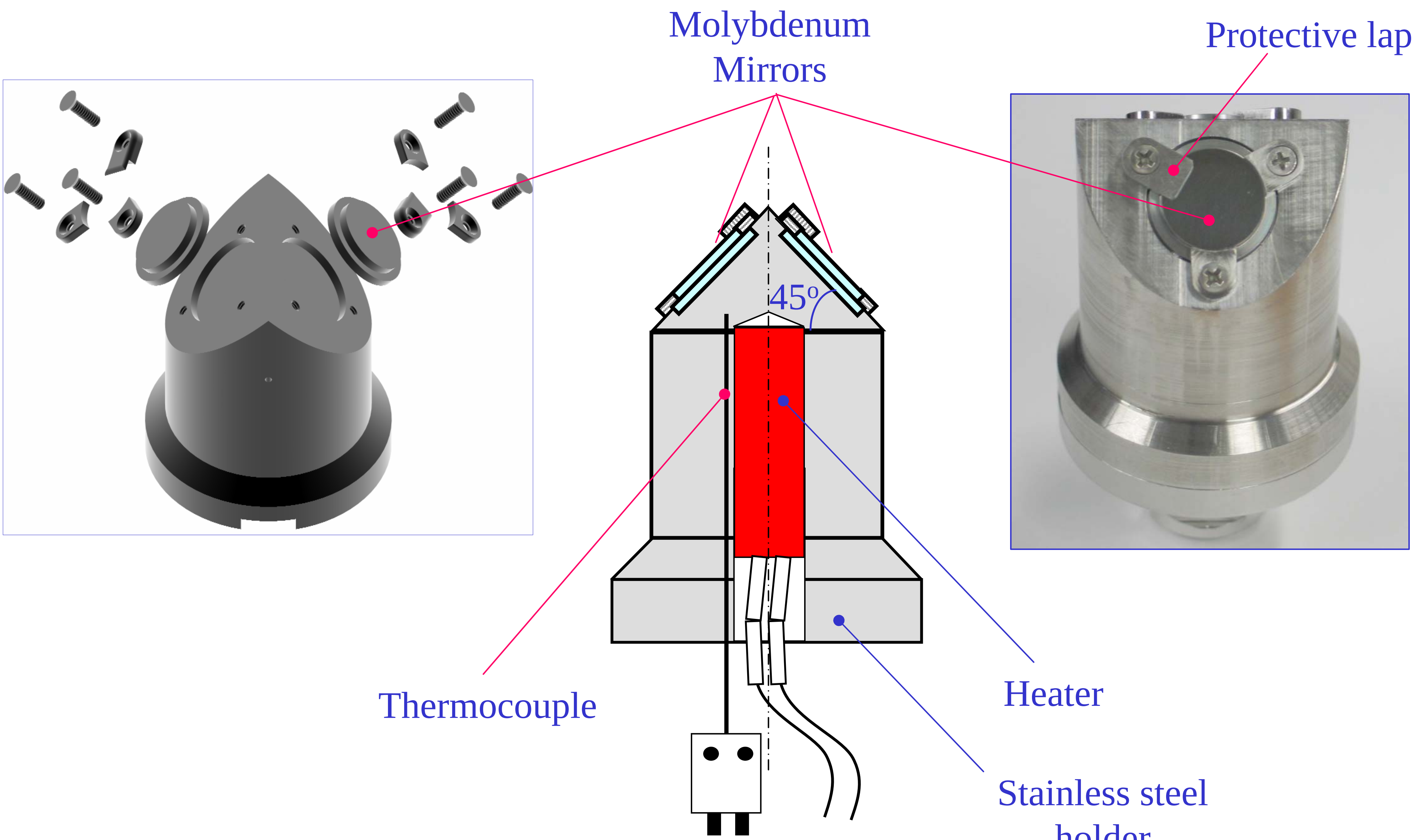
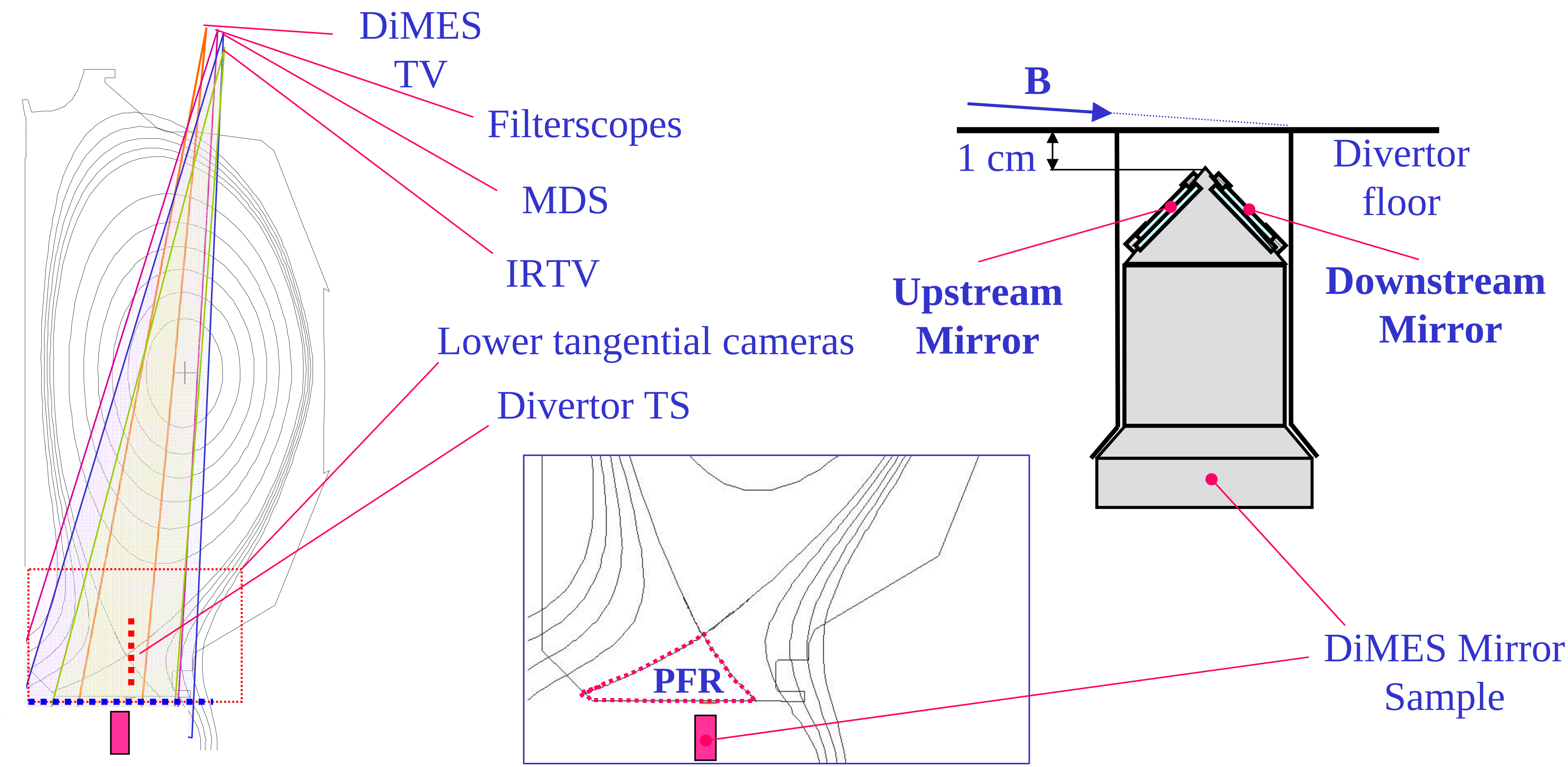
Mirror DiMES experimental concept and design



Mirrors supplied by A. Litnovsky of Forschungszentrum Jülich

Mirror DiMES exposure geometry

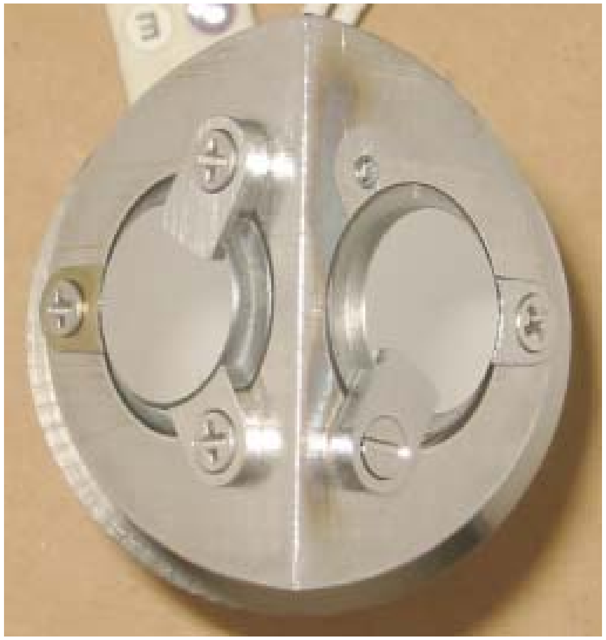


- Lower Single Null SAPP-like shape
- DiMES located at the Private Flux Region
- Piggyback on C13 injection experiment: highly reproducible partially-detached (PDD) ELMing H-mode discharges

Two exposures at different temperatures

- First set of mirrors was exposed at about 30º C to 6 discharges for a total of ~ 25 sec
- Visible deposits were found on both mirrors and holder elements upon removal

- The second mirror set was exposed to 17 discharges for a total of ~ 70 sec at elevated temperature changing from 140º C to 80º C (planned exposure at 400º C but heater failed)
- Upon removal, virtually no deposits were visible on the mirrors
- Some of the deposits formed on the mirror holder elements in the previous exposures were gone



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Deposition is suppressed at elevated temperature

Non-heated mirrors

Upstream

Downstream

Heated mirrors

140^{o}C→ 85^{o}C.

Upstream

Downstream

Secondary Ion Mass Spectrometry (SIMS) measurements locations

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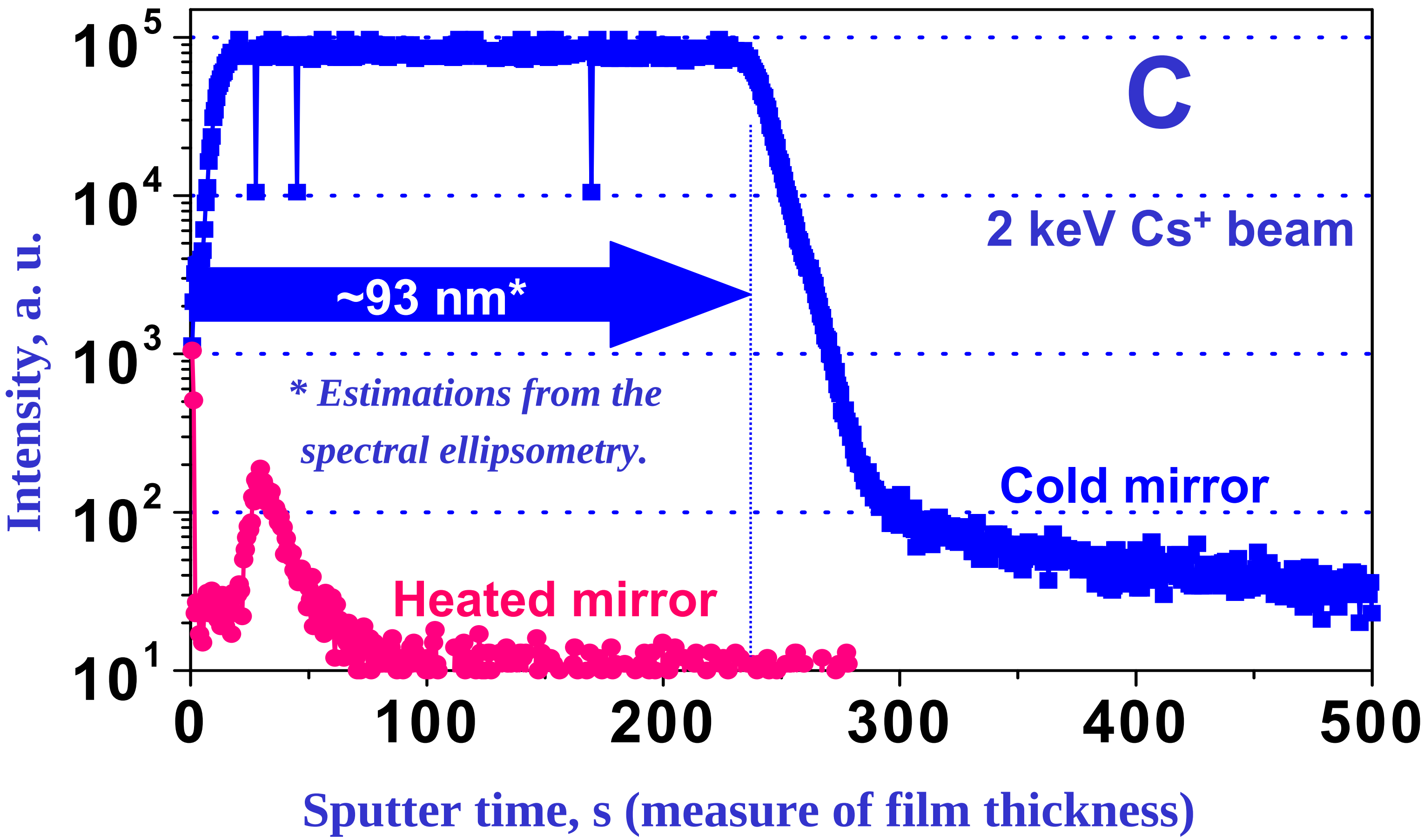
Courtesy of A. Litnovsky

SIMS shows significant C deposition on the cold mirror and virtually no deposits on the heated mirror



Deposition rate of ~ 4 nm/sec at room temperature

Potentially a very good news for ITER:

it may be possible avoid deposition by moderate heating of diagnostic mirrors

Courtesy of A. Litnovsky

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Summary of results

- At 200º C we observed net carbon erosion at a rate of ~ 3 nm/sec from a plasma-facing surface under detached conditions, where normally net deposition is observed

- At 200º C carbon deposition down a simulated tile gap was reduced by about a factor of 2 - 4 and D co-deposition by an order of magnitude compared to those at room temperature

- Carbon deposition was observed on molybdenum mirrors recessed below the divertor floor at room temperature and was fully suppressed at elevated temperature between 140 and 80º C

More experiments are needed!

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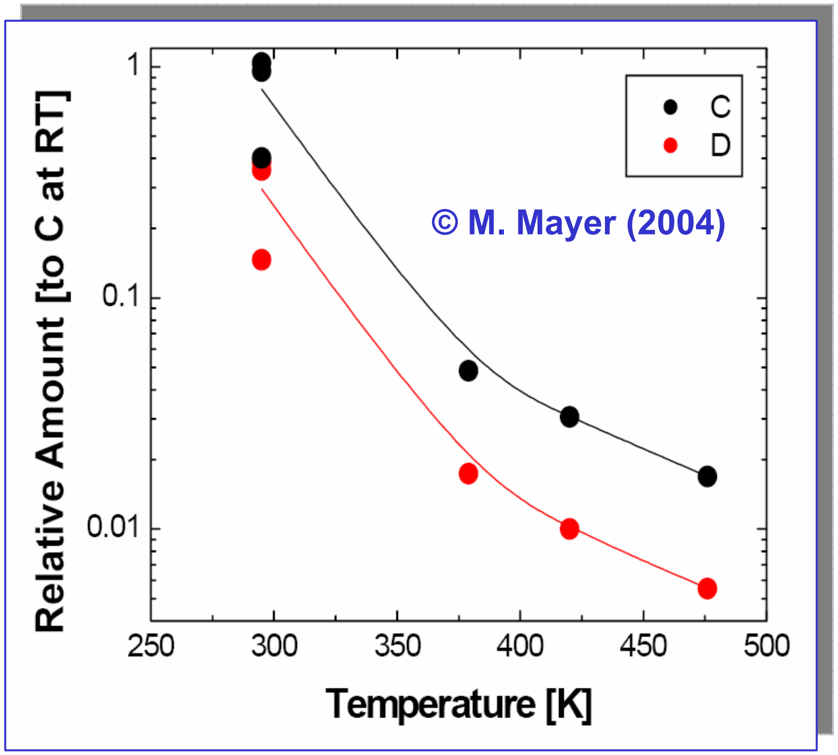
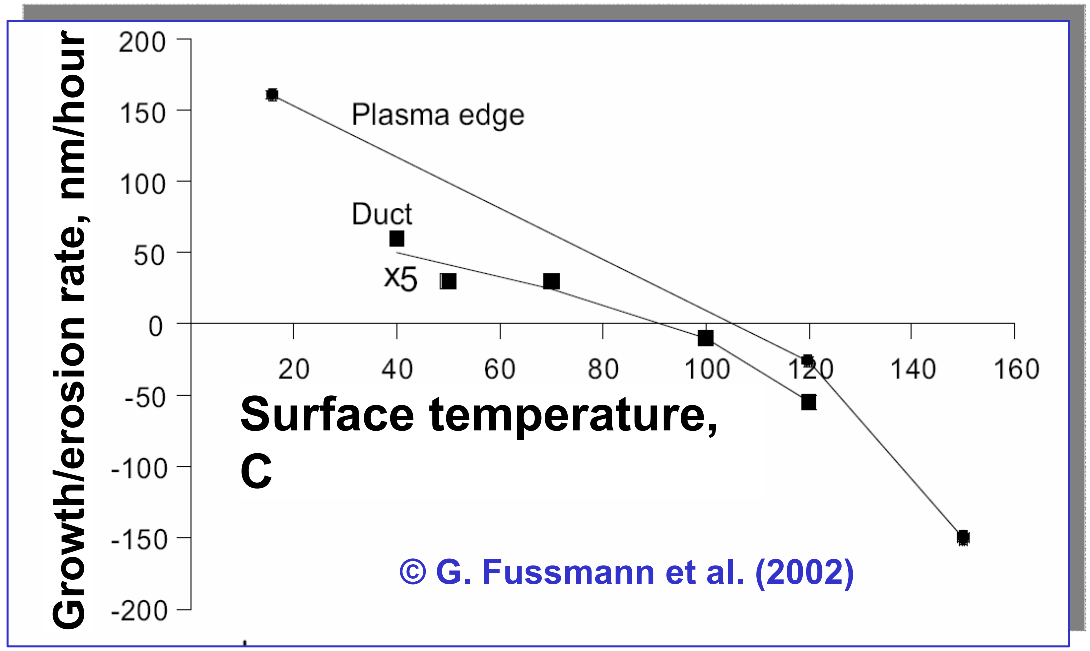
Our results are in agreement with AUG divertor data[1] and lab tests[2]

Heatable collectors in AUG divertor



a:C-H film growth in PSI-2 Simulator



Data used:
1. J. Roth, 12th European Fusion Physics Workshop, Witney, 8.12. 2004;
2. G. Fussmann et.al. Construction and Testing of Divertor Liner Components", EFDA Report 2002

Courtesy of A. Litnovsky

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