USXR Arrays for MHD Activity and Equilibrium Measurements in NSTX

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Summary of proposed work

I **Completion of poloidal USXR system for ‘two-color’ poloidal tomography**

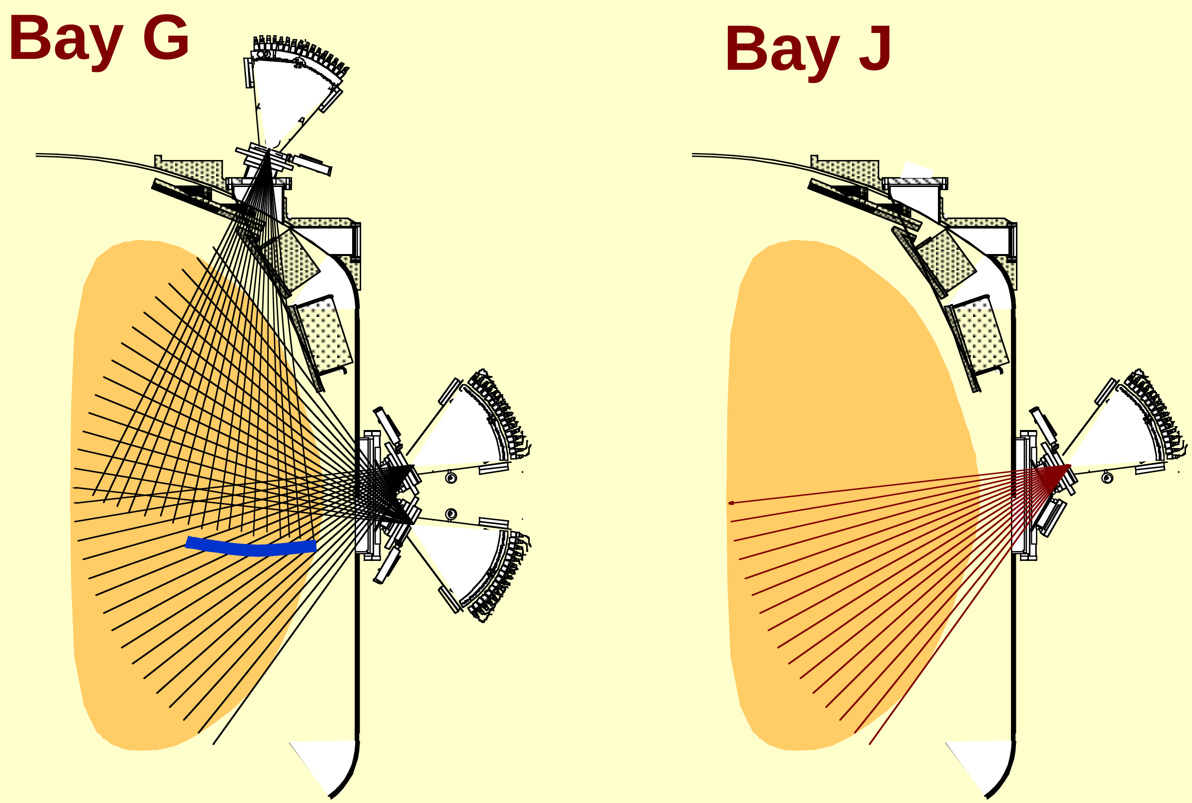
II **Development of 2-D 100 kHz USXR array for tangential imaging of NSTX core and periphery**

III **MHD applications of GEM detector *(FTU/JHU/PPPL collaboration)***

I

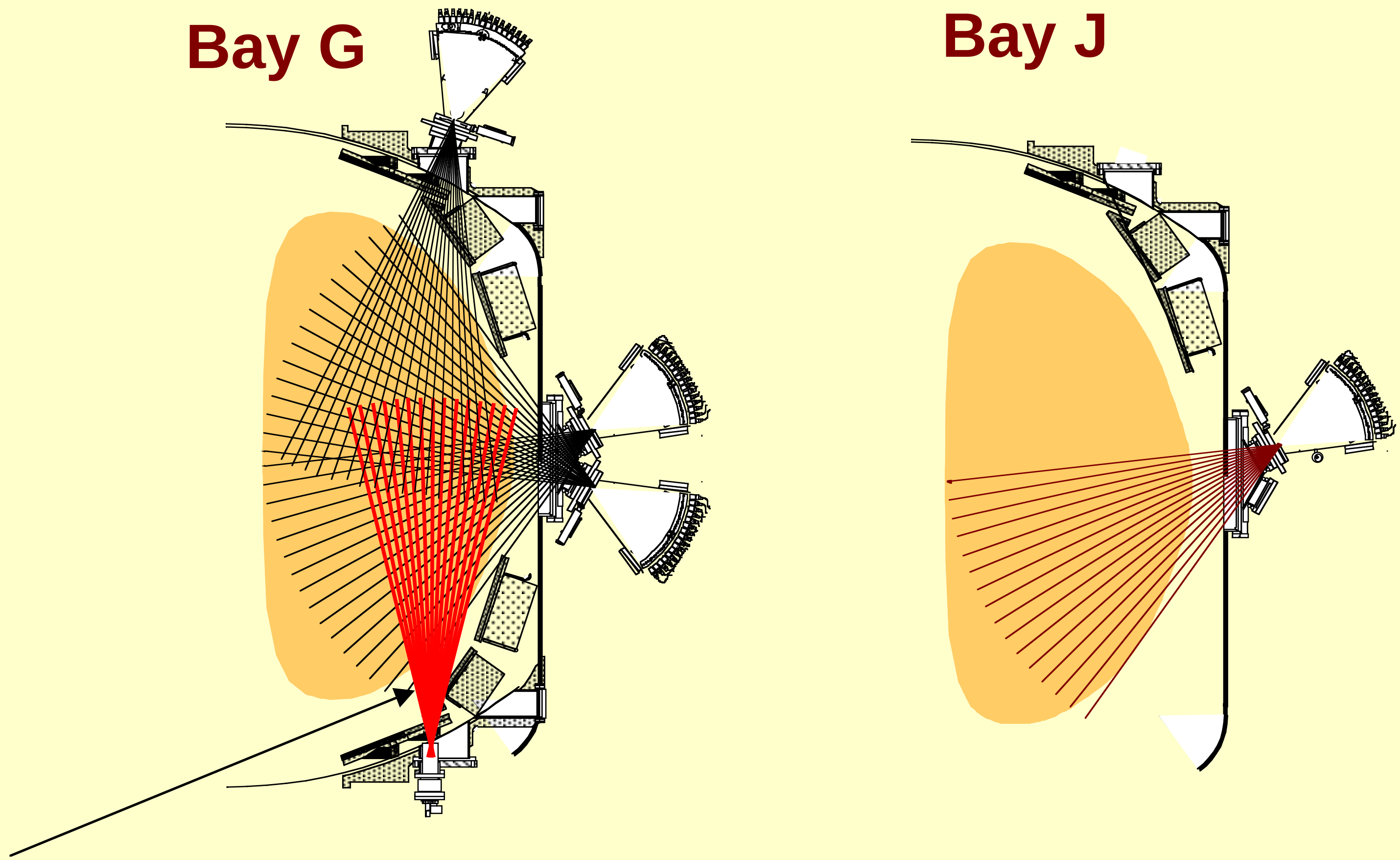
Completion of poloidal USXR system

Poloidal USXR system at present



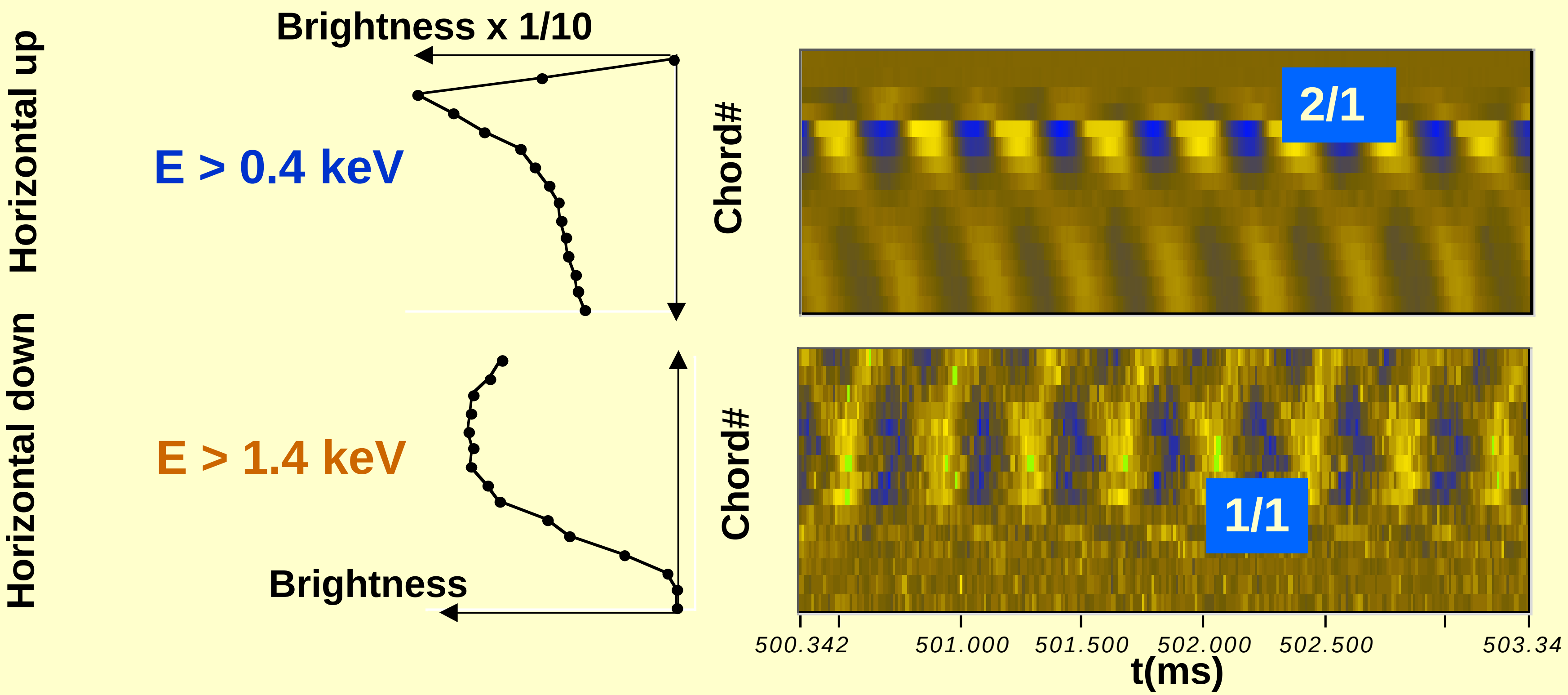
- **Vertical chords 0-8 vignetted**
- **Arrays used for MHD *imaging* and transport measurements**
- **Bay J array for toroidal MHD and P_{rad} fluctuations**

Poloidal USXR system for the next run



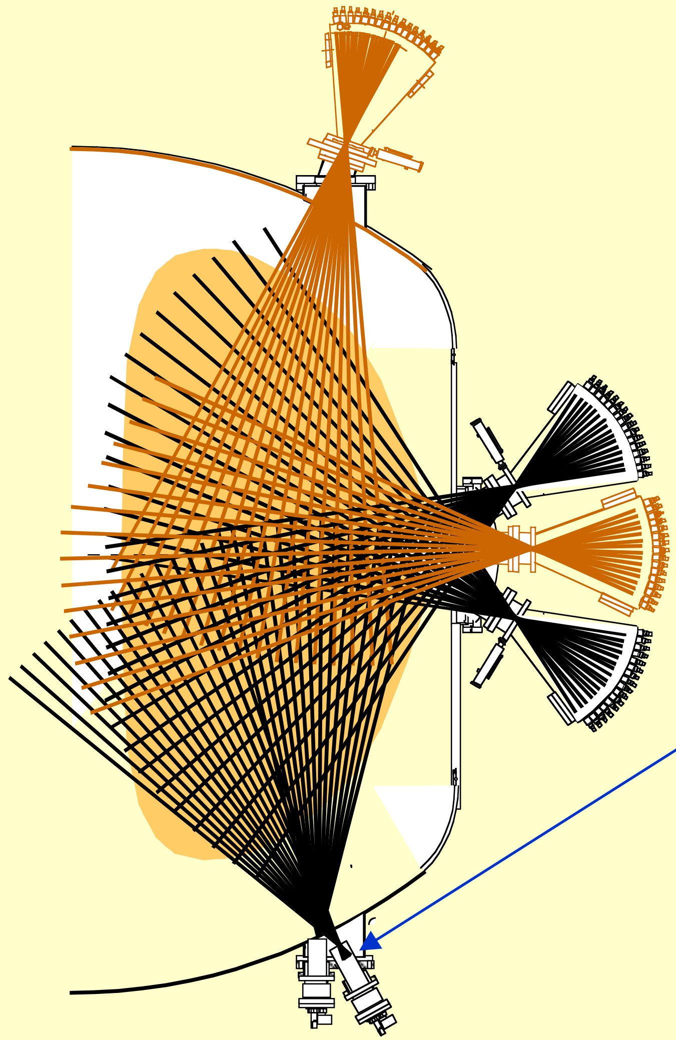
- Re-entrant miniature array developed to solve vignetting problem
- Tomography implemented in collaboration with R. Granetz, MIT
- Insufficient inboard coverage for broad H-mode profiles

Why 'two-color' tomography



- Electron temperature perturbations associated with MHD activity
- In addition, core MHD 'hidden' by peripheral modes during H-mode due to strong enhancement of E > 0.4 keV emission at periphery
- Simultaneous E > 1.4 keV imaging allows 'seeing' only core MHD

Final USXR poloidal system
(96 chords at Bay G)



Core system
Old top array +
Old Bay J array

Full view system
Old horizontal arrays +
2003 reentrant array +
New reentrant array

- **Computational work: - improved tomography algorithms (e.g., SVD/CT)**
  - MDS user interface for USXR data

II 2-D 100 kHz USXR array for tangential imaging

- **Poloidal tomography effective for m ≤ 2 internal modes**

- **It cannot resolve structures that evolve on a time scale much different from the plasma rotation (wall modes, ELMs, REs), or structures with short poloidal wavelength (inboard in a ST)**

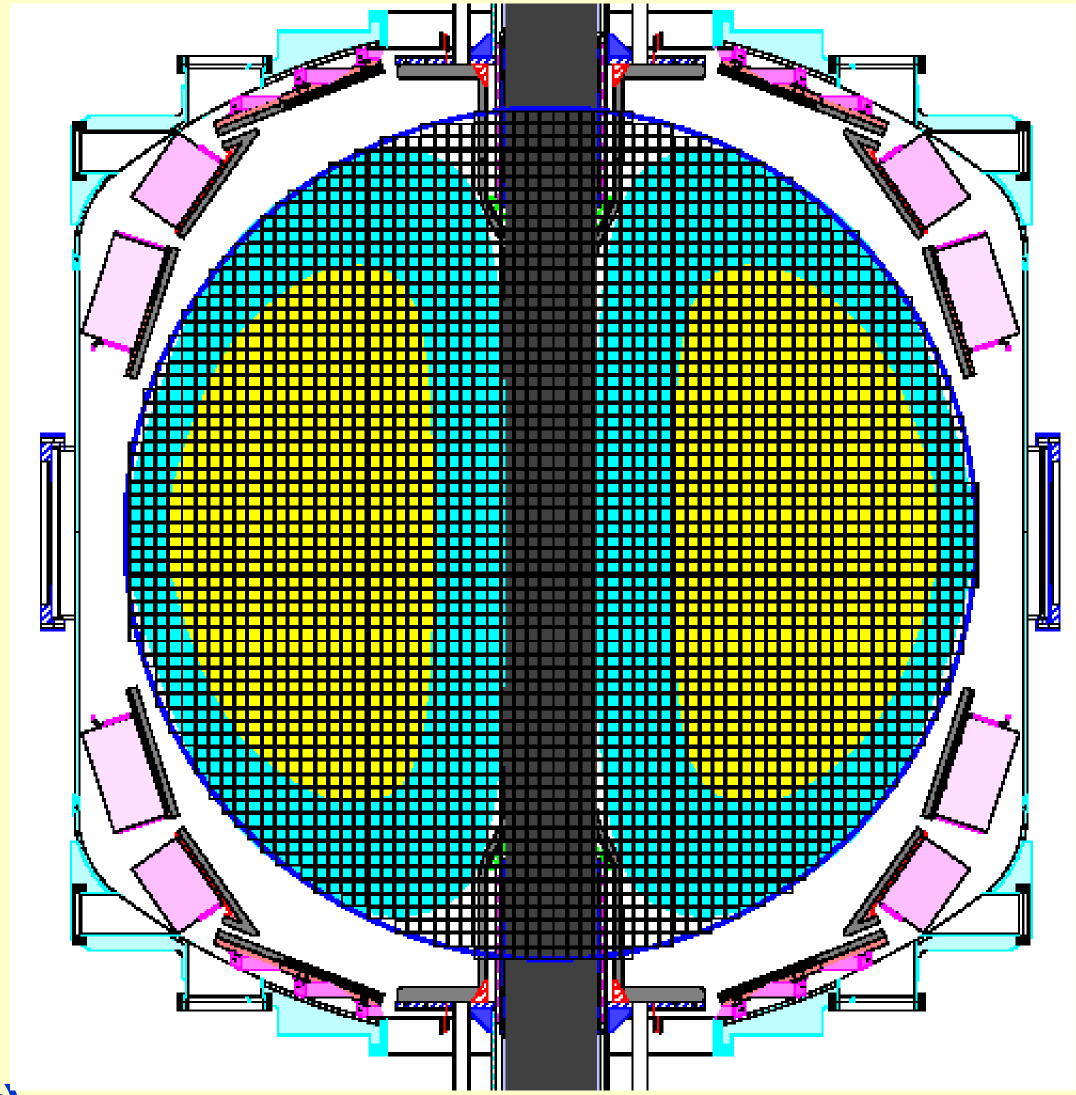
- ***Fast 2-D tangential imaging of the entire plasma cross section*** **needed to resolve the high-m instabilities and decouple the measurements from rotation**

- **System requirements: ≤ 10 μs time resolution and ≥ 100 signal-to-noise (see “NSTX ‘Measurement Needs” and USXR data)**

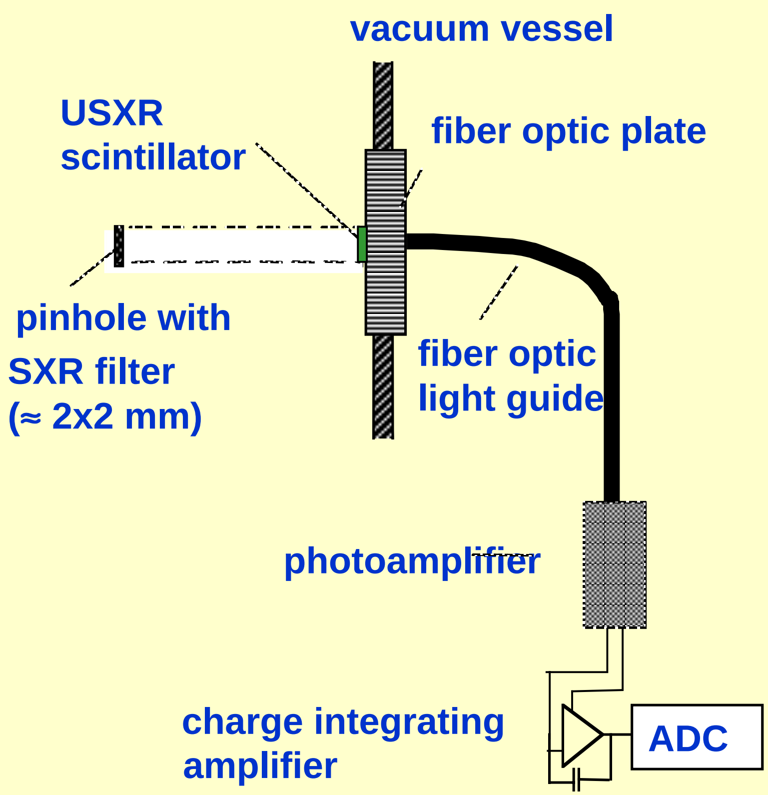
- **JHU now investigating large pixel-count (1000s of pixels) USXR arrays capable of continuous sampling at ≥ 100 kHz for several seconds and having ≥ 100 signal-to-noise-ratio**

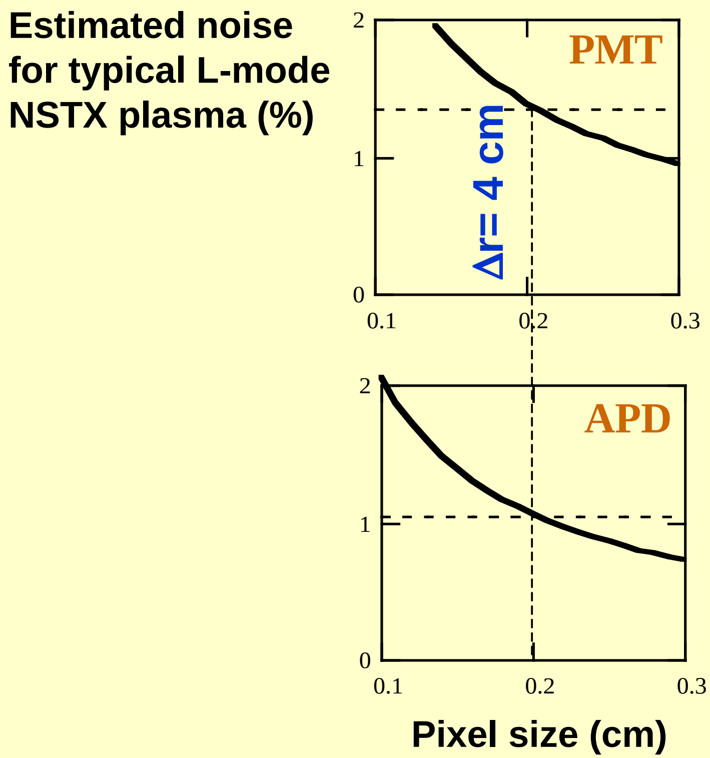
Proposed 2-D USXR array

- **4096 (64 x 64) channels**
- **100 kHz continuous sampling for ≈ 5 s**
- **≈ 0.04 -10 keV range**
- **≈ 4 cm spatial resolution**
- **SNR ≥ 100**
- **Tangential view of entire plasma for simultaneous poloidal and toroidal mode structure (*D. Gates*)**



Optical USXR array concept

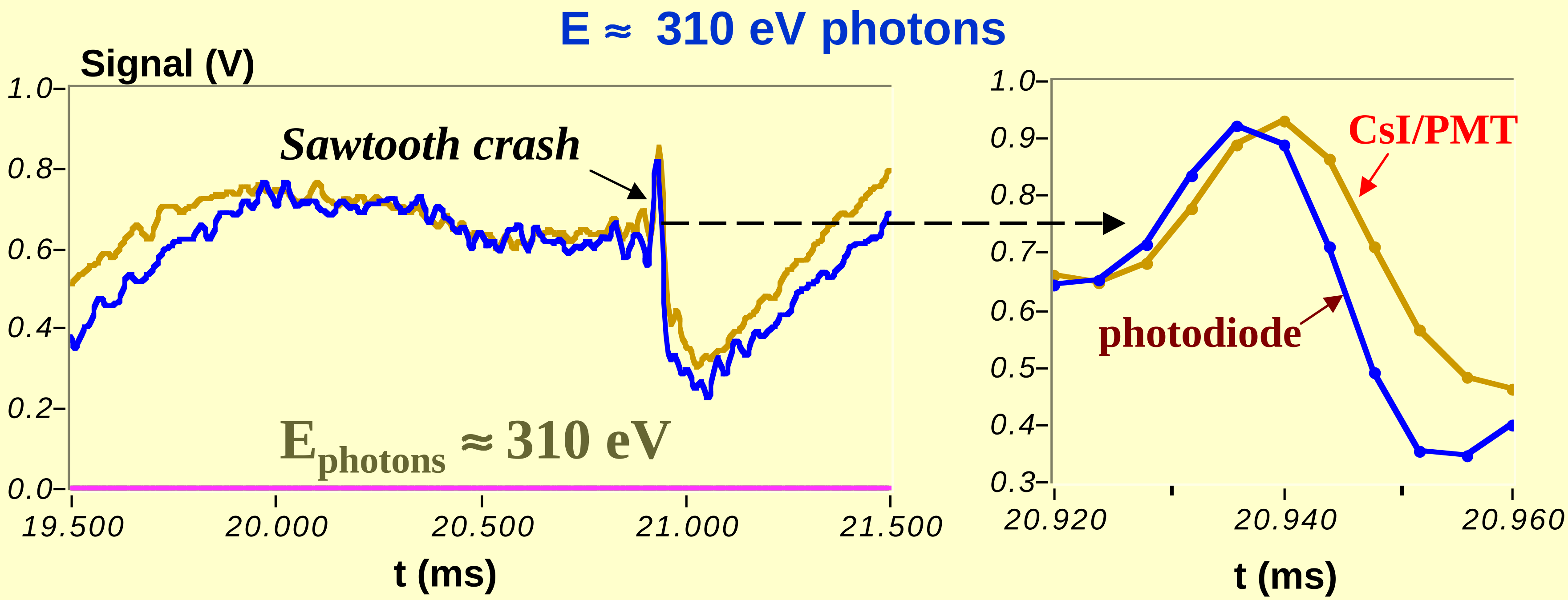




- Very efficient USXR scintillator preserves X-ray statistics
- Large, discrete pixels all the way through (no demagnification)
- Low gain/noise photoamplifier converts optical signal -> 100s nA current

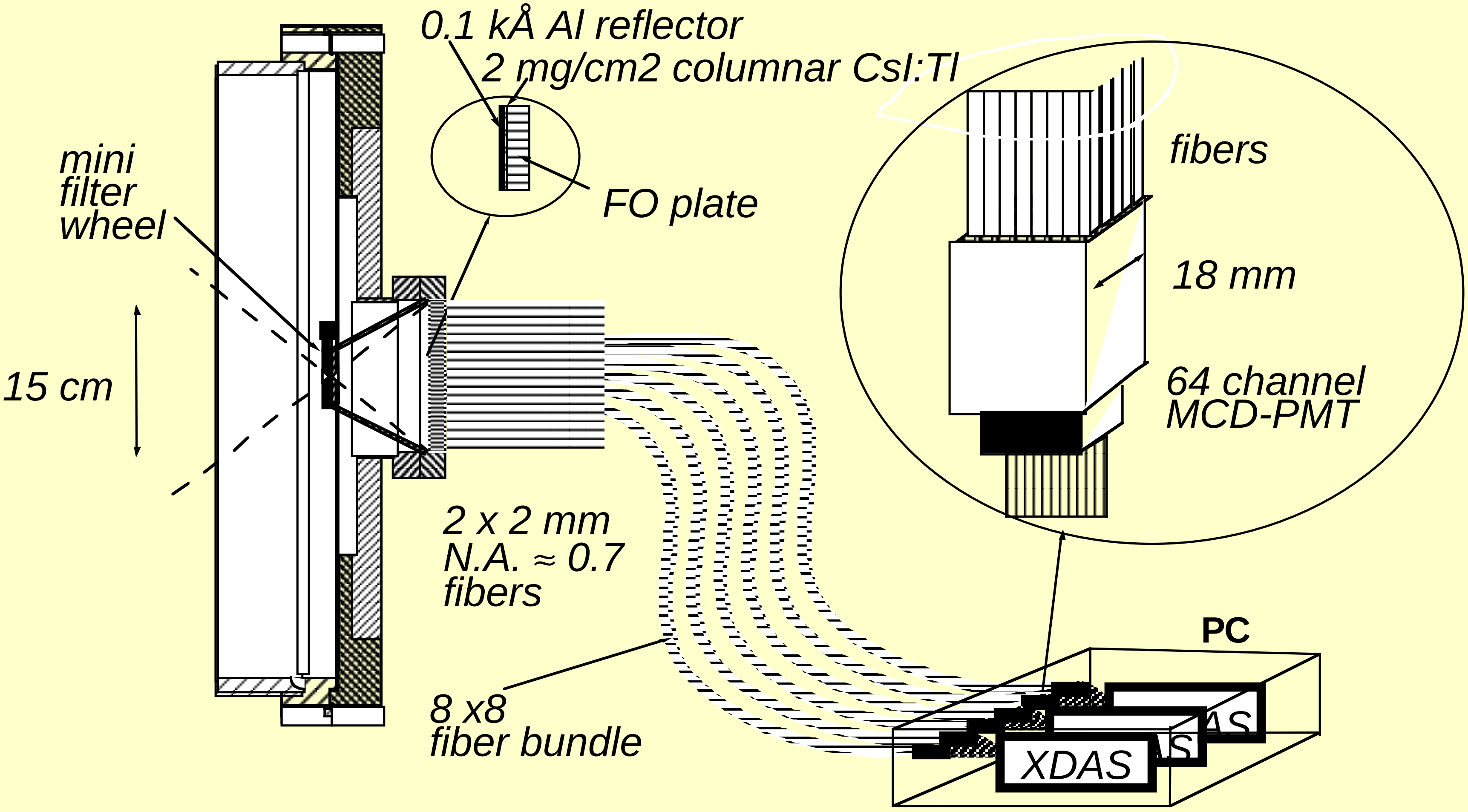
- Charge integration replaces current/voltage conversion for fast (≈ 100 kHz), low noise and cost efficient DAQ on thousands of channels

Optical channel vs. photodiode channel on CDX-U



- Optical signal-to-noise-ratio superior to that of photodiode
- CsI:Tl time response in the USXR ≈ 12 μs
- CsI(Na) being tested (0.1 μs response and twice as efficient)

Layout of 2-D tangential USXR array



- **Signal readout and digitization using 32 x 128-channel ASIC developed for X-ray inspection (XDAS, Electron Tubes Ltd.)**

Development status

- **Optical USXR array concept successfully tested**

- **Prototype 128-channel array for next NSTX campaign**

- **Existent XDAS board (10 μs frames at 10 kHz frame rate) tested successfully for ≥ 100 signal-to-noise ratio with 10 μs frames**

- **Upgrade of digitizers and memory in XDAS board for 100 kHz frame rate agreed with the manufacturer**

- **NSTX 2-D USXR array feasible on a two year horizon**

Work performed under the DoE Diagnostic Development Program

III MHD applications of GEM detector
Equilibrium reconstruction

- 2-D tangential GEM detector operated in ‘threshold scan’ mode can provide map of approximate line-of-sight T_e, similar to PHA
  (see D. Pacella’s contribution at this Forum)

- MPTS data suggests that in most cases T_e is flux surface function

- Flux surface shape (core especially) correlates with current profile

- T_e iso-surfaces obtained with GEM could provide improved constraint for EFIT reconstruction of current profile

- Technique complementary to SXR imaging of plasma shape (B. Stratton and R. Kaita)

- 1000 pixel GEM under development in Italy

MHD temperature perturbations

- ECE not applicable for fast, local ΔT_e measurements in NSTX
- In 'fixed threshold' mode the GEM has time resolution up to 0.05- 0.1 ms
- By alternating 'high' and 'low' threshold pixels on a T_e iso-surface, one could measure local ΔT_e changes due to f ≤ 10 kHz MHD perturbations
- The ΔT_e calibration obtained with the GEM could then be transferred to the 'two-color' USXR system in order to extend the measurements to f > 10 kHz