MCP/Timepix soft X-ray event counting detectors: current and near future capabilities

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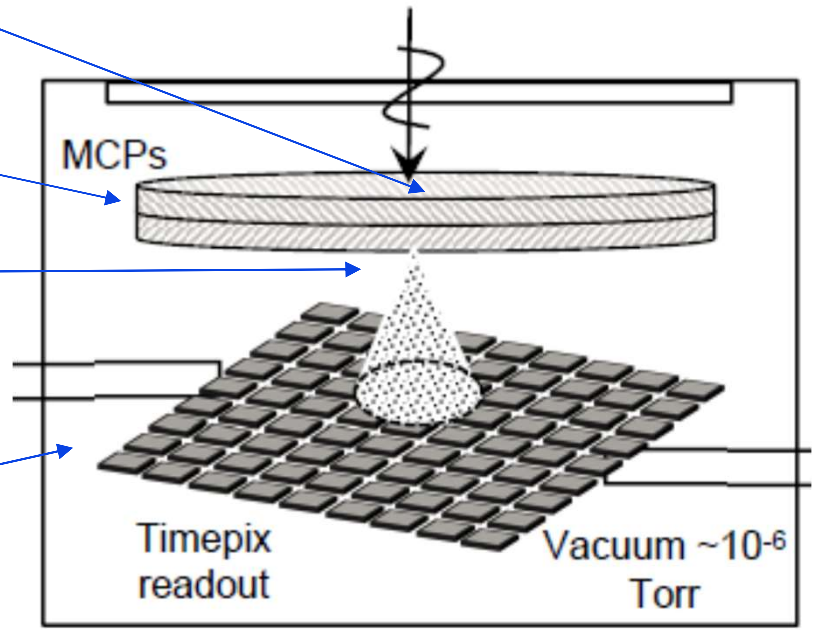
MCP detector configuration for soft X-ray applications

- Photocathode converts photon to electron
- MCP(s) amplify electron by 10^3 to 10^7
- Rear field accelerates electrons to readout
- Different readouts can be used, optimized for particular application

Photocathode is deposited directly on MCP



No ideal detector fitting all applications. Compromises are always to be found.

Advantages/disadvantages of MCP detectors in photon counting applications

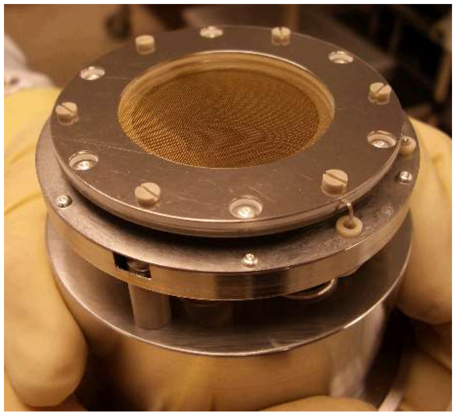
- **No readout noise**
- **Time and position for every detected particle** (~6 μm with event centroiding, ~20 ps event spread time in MCP)
- **Event counting**
- **TOF applications**
- **High counting rates** possible with latest readouts
- **High detection efficiency (neutrons, soft X-rays)**

- **No intrinsic energy resolution**
- **Small area (~ 3 cm, may be up to 10 cm)**
- Require **vacuum**
- Require **high voltage**
- **Image distortions**

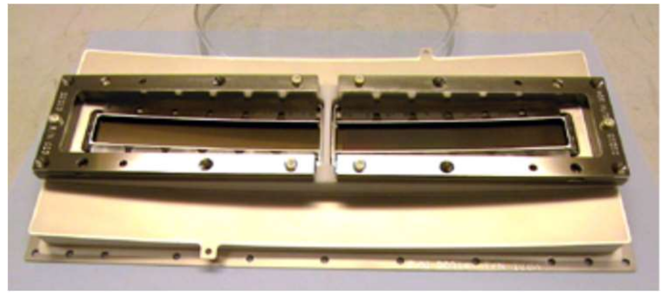
Highly generalized!

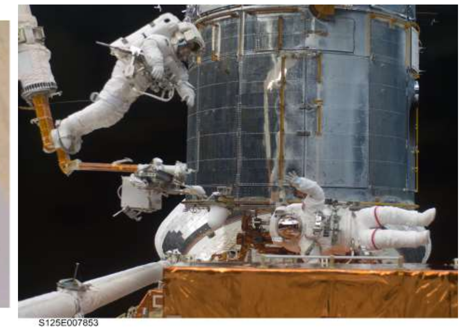
Detector hardware implementations

Synchrotron beamline detectors:
ARPES – angular resolved
photoelectron emission spectroscopy



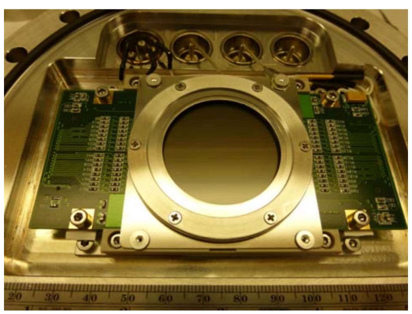
COS detector
Installed on Hubble telescope



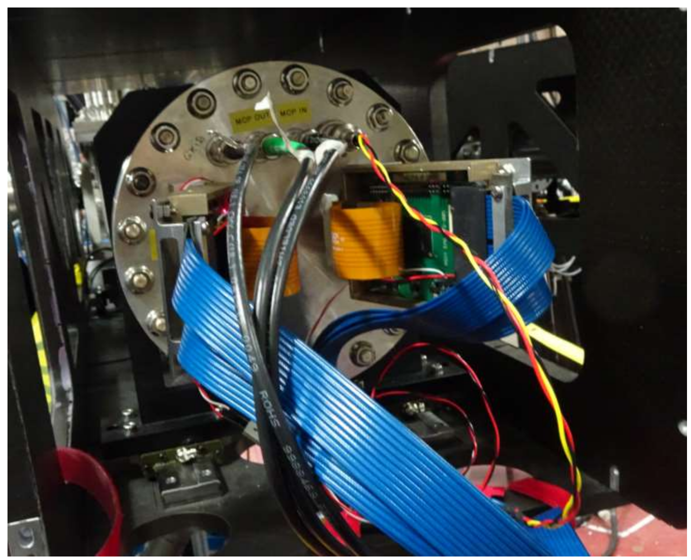


NASA Shuttle STS-125 Mission

RIXS and XPCS @ ALS



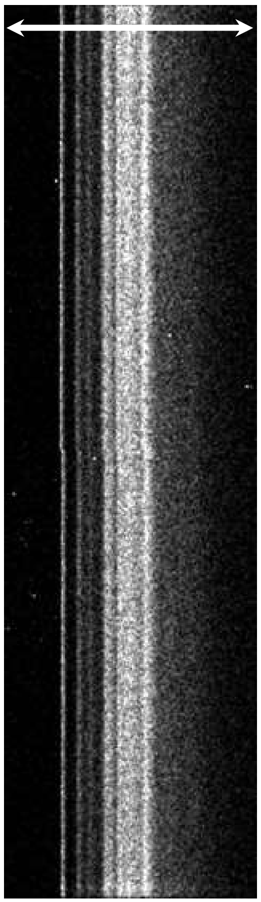
ALS MCP/Timepix detector,
used at LCLS once



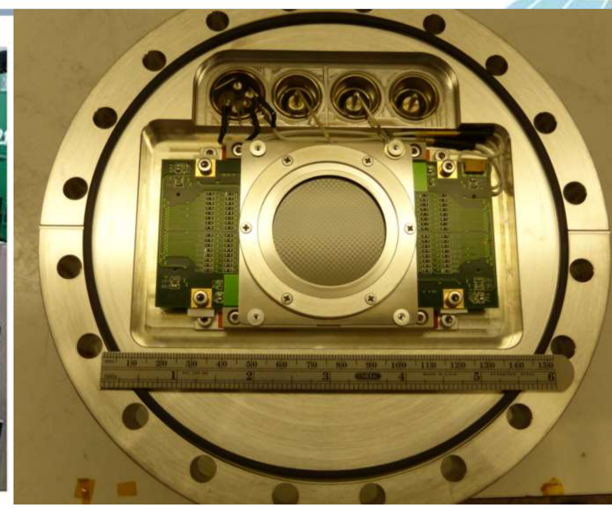
Scientific Reports (2020) 10:22226
Phys. Rev. Let 125, 116401 (2020)
Phys. Rev. Let 126, 117201 (2021)

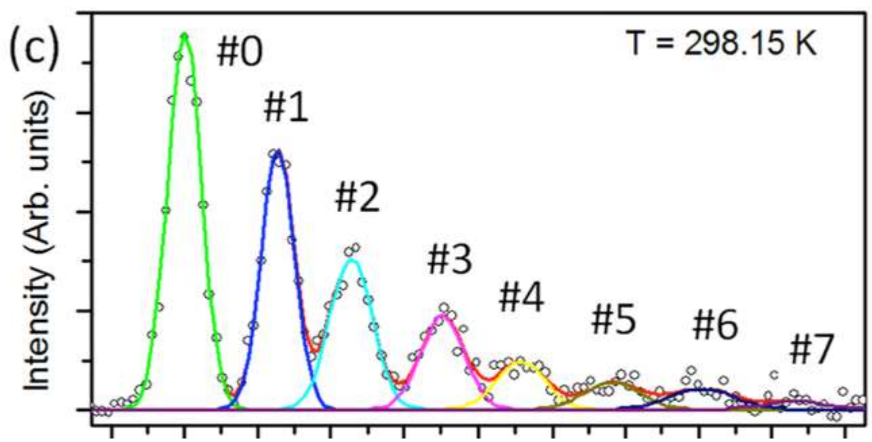
Initial tests of MCP/TPX systems at ALS and LCLS

~8.5 mm



Raw image

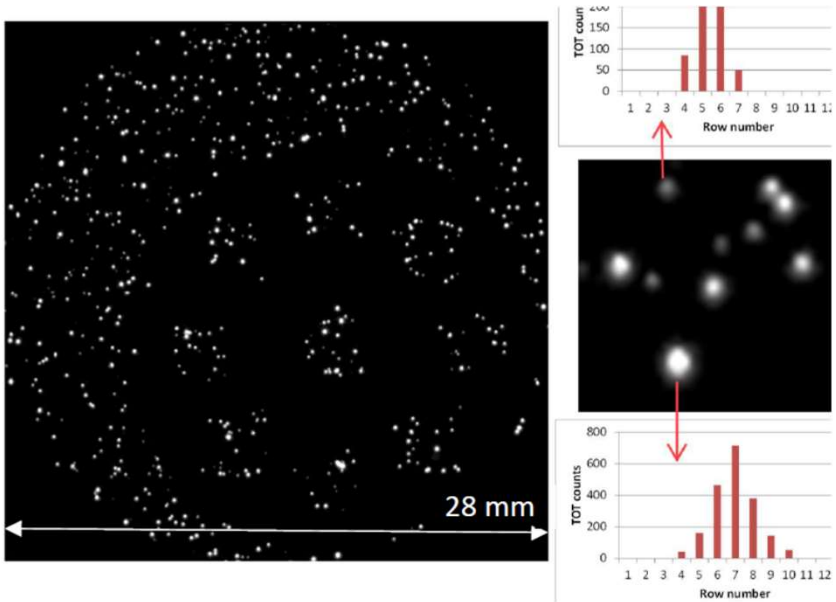


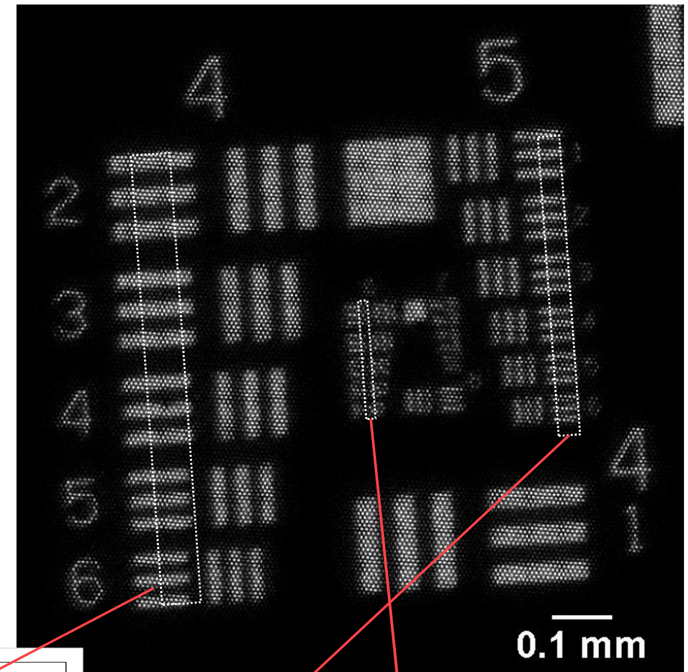


X. Feng et al., Phys. Rev. Let 125, 116401 (2020)

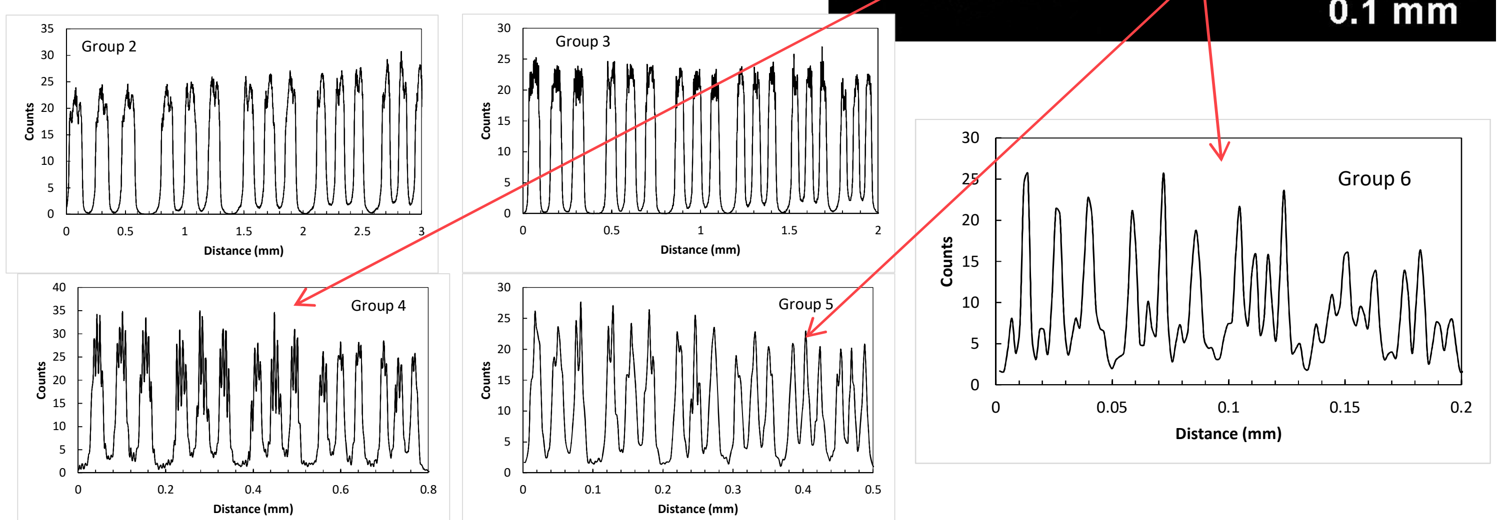
HOPG elastic peak vibronic coupling

Centroided images: ~6.5 μm resolution



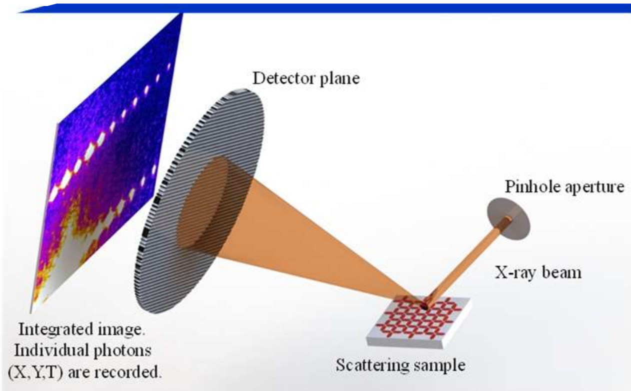


Cross sections through resolution mask



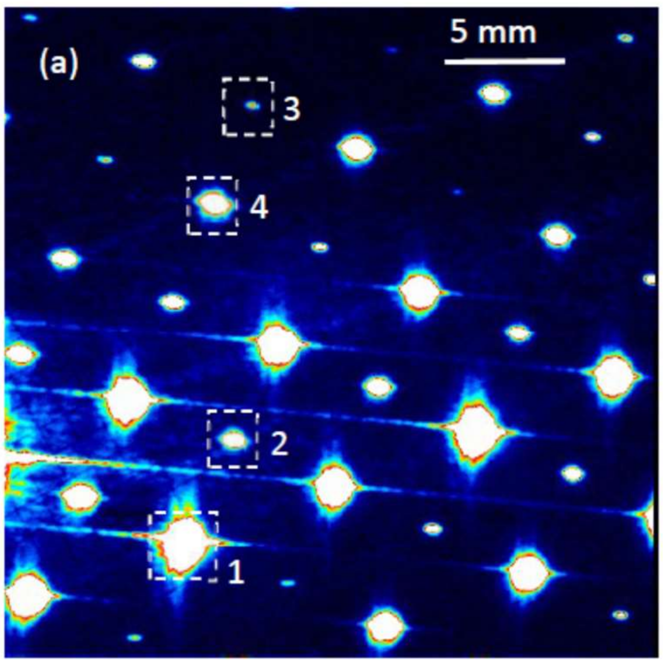
A.S. Tremsin, et al., JINST **13** (2018) C11005

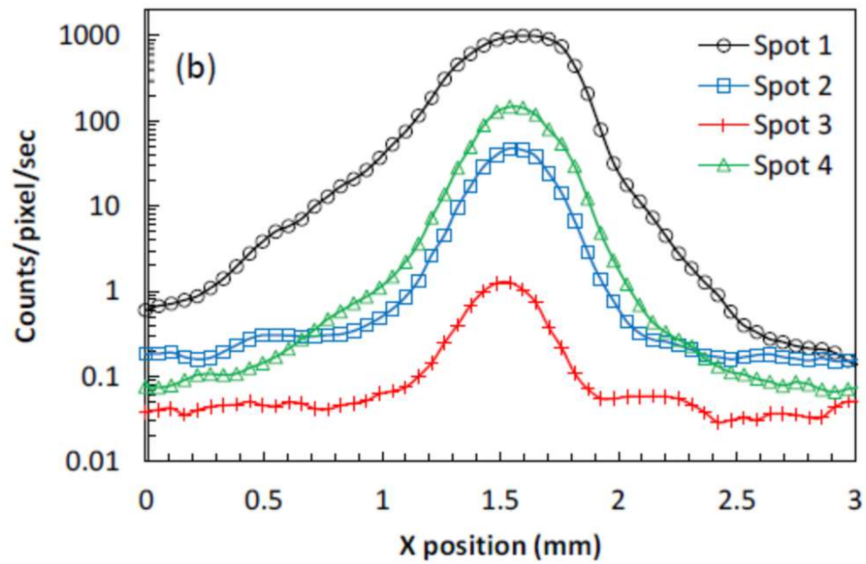
Development of 2x2 MCP/TPX3 detector



Beamline experiments on the MCP optimization

- MCP/Timepix detectors enable operation at a very large dynamic range (photon counting within very bright and very dim spots at the same time).
- The count rate within different spots in that image





MCP/Timepix soft X-ray detectors roadmap

Gen. 2 (used now)

- **Spatial resolution** 55 µm with 10 ns timing resolution
- **Either** high spatial resolution (~6 µm), **or** high timing resolution
- **Count rate** in high spatial resolution (~6 µm), is **limited to ~3 MHz**
- **Count rate** with 10 ns and 55 µm is ~ **30 MHz**
- **320 µs** readout time **(dead time)** per frame
- **Power dissipation** ~1W/chip

Gen. 3 (developed UCB/ALS)

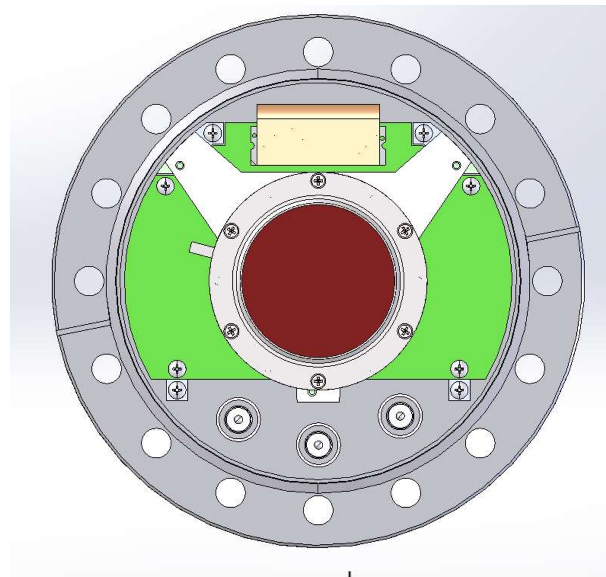
- **Timing resolution improved to ~2 ns**
- **Both high spatial** (~6 µm) **and timing resolution** (~2 ns) are possible
- **No dead time for readout: event driven readout**
- **80 Mhits/s rate per chip**
- **More heat generated in vacuum** (power dissipation ~2 W/chip); power options can be optimized
- **Longer cable out of vacuum** (LVDS signal output)

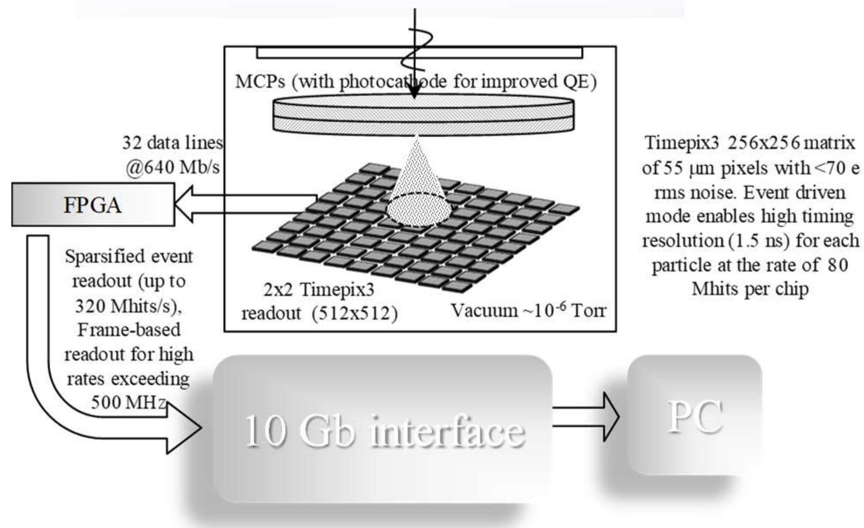
Gen. 4

- **Timing resolution to be improved to <200 ps**
- **Larger area per chip** (512x488 pixels, 55 µm each)
- **4-side buttable** (TSVs)
- **Very high data output rates** (up to 160 Gb/s)

Development of 2x2 MCP/TPX3 detector

- **2nd phase of the program**: Design of quad 2x2 MCP/TPX3 detector is underway.
- Mechanical design of vacuum hardware. The currently planned mounting on a 6 inch flange is finalized (ASIC in-vacuum board and high speed vacuum feedthrough/connector)
- Design, implementation and optimization of data acquisition firmware for 4 chip readout electronics: use existing 1 chip version.





Thank you for your attention!

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The work on MCP/Timepix detector was done within the Medipix collaboration.