Fast X-Ray Detectors for the APS and Elsewhere

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X-Ray Detector Needs

What is already out there

Synchrotron

Medical

Application examples

MCP or columnar structure as photocathode

A positively gated photocathode for nuclear resonance
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X-Ray Detector Needs

- Synchrotron: 2-d spatial and/or time resolution
- XFEL: 2-d spatial resolution, tons of x-rays
- Medical: imaging, PET
- Homeland security: large-area imaging
- Some special applications
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What is Already Out There

- CCDs: direct-absorption and scintillator; can be gated, in principle, to $\mu$s or so, but not usually done. Spatial resolution down to a few microns, without gating down to ms resolution, $\$$ / cm$^2$

- Pixel-array detectors, can be gated to 100 ns, spatial resolution ca. 100 microns, without gating down to $\mu$s resolution, depending on ROI, $\$$ / cm$^2$

- Wire chamber (gas avalanche amplification): location/time-tagged events $\mu$s resolution, area is cheap

- Our detector produces a stream of location-time-tagged events, not just events in a gate interval. Like wire chamber, but faster/higher rate and better x-ray stopping power, area is cheap
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- Synchrotron: 2-d spatial and/or time resolution
- wide range of event rates, possibly spatially highly inhomogeneous photon load
- use scintillator with visible-light photocathode: slow response or low efficiency
- planar, direct-conversion photocathode: fast, low efficiency
- NB: at synchrotron, 100 ns time resolution is as good as 100 ps (bunch duration), faster than 100 ps very valuable
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- High detection efficiency at higher photon energies: 30..150 keV, or even 511 keV for PET
- medical x-ray needs “no” time resolution, absorption-edge angiography could profit from ca. 1 ms, PET needs 100 ps or better
- large area
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Application Example: Protein Crystallography

white-beam Laue diffraction: one crystal, many $\lambda$

rotate crystal to obtain series of diffraction maps intensities in diffraction space FT into structure

LAPPD instead of CCD:
no readout overhead rapid rot., continuous readout
Example: Dynamic Light Scattering of X-Rays

time evolution of spatial correlations

measure correlation of speckle patterns at 2 times

homodyne speckle

heterodyne speckle

challenge: wide dyn. range

Example: XFEL: Tons of Photons in a Pulse

Problem at XFEL: Detector overload by huge pulse
solution: spread flux in time and space
in time: use efficient, slow scintillator
in space: grazing incidence
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Leverage MCP/ALD technology developed in LAPPD

electron escape depth ca. 100 nm
x-rays mostly pass through CsI
10 keV → ca. 1% abs.

use grazing incidence
→ MCP or nanocolumns
with ALD’d photocathode
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Nuclear Resonance, Time Domain

forward scattering from foils of increasing thickness

v. Bürck et al., PRB 46, 6207-6211 (1992)

Thickness Dependence of Nuclear Forward Scattering

Intensity (arb. units)

Time (ns)

(a) $d = 0.5 \mu m$

(b) $d = 1.0 \mu m$

(c) $d = 1.66 \mu m$

(d) $d = 3.3 \mu m$

(a) $d = 9.5 \mu m$

(b) $d = 12.8 \mu m$

(c) $d = 16.1 \mu m$

(d) $d = 28.5 \mu m$

speedup dynamical beats
How this is measured on a synchrotron

Using synchrotron radiation: pulsed, broadband source

Problem: detector is “dead” for ca. 10ns after SR pulse

Hastings et al., PRL 66, 770-773 (1991)
Gated MCP

new idea:
use gating pulse to actively clear out MCP for 100 ps during SR pulse
MCP is ready 100 ps after SR pulse, no “afterglow”

100-ps gated MCP

Katayama et al.,

10^{-10} contrast possible?