Fast X-Ray Detectors for the APS and Elsewhere

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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 μs or so, but not usually done. Spatial resolution down to a few microns, without gating down to ms resolution, $$ / cm^2
- Pixel-array detectors, can be gated to 100 ns, spatial resolution ca. 100 microns, without gating down to μs resolution, depending on ROI, $$ / cm^2
- wire chamber (gas avalanche amplification): location/time-tagged events μs 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

- 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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Medical

- 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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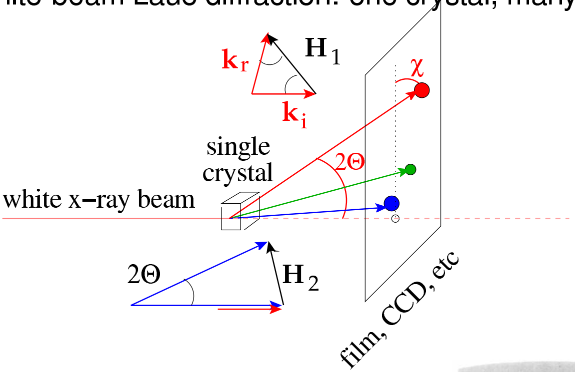
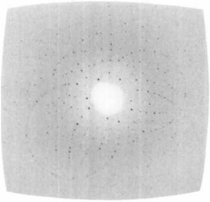
Application Example: Protein Crystallography

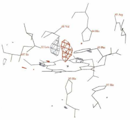
white-beam Laue diffraction: one crystal, many λ



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

LAPPD instead of CCD:
no readout overhead
rapid rot., continuous readout



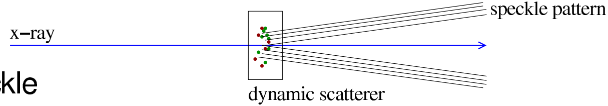


Example: Dynamic Light Scattering of X-Rays

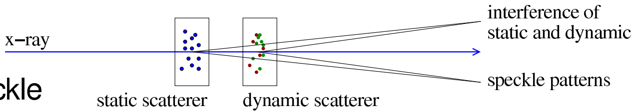
time evolution of spatial correlations

measure correlation of speckle patterns at 2 times

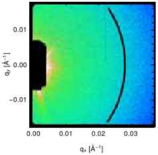
homodyne speckle



heterodyne speckle



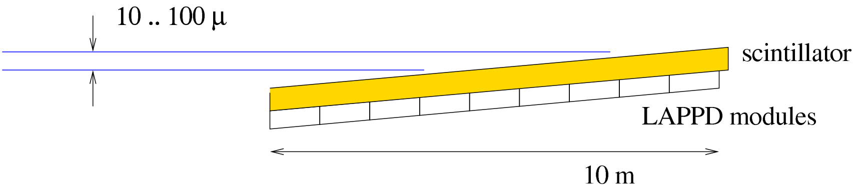
challenge: wide dyn. range



M. Sutton et al., Opt. Expr. **11**, 2268-2277 (2003)

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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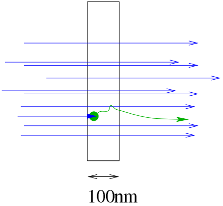
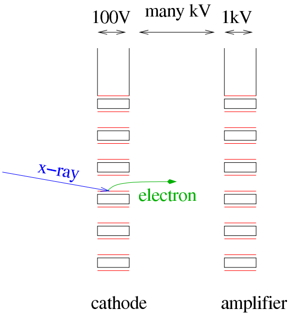
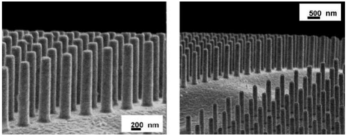
MCP or columnar structure as photocathode

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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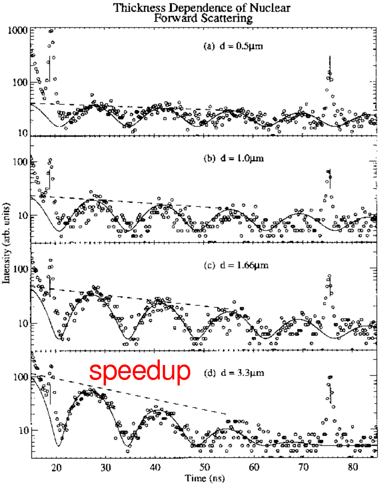
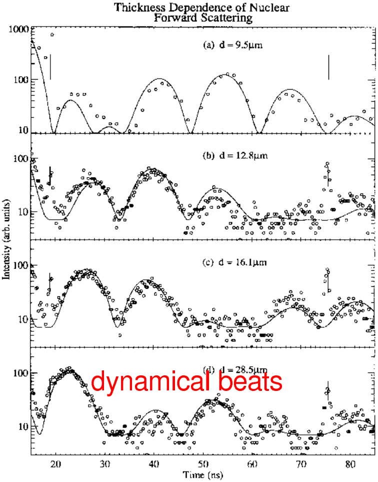
Nuclear Resonance, Time Domain

forward scattering from foils of increasing thickness

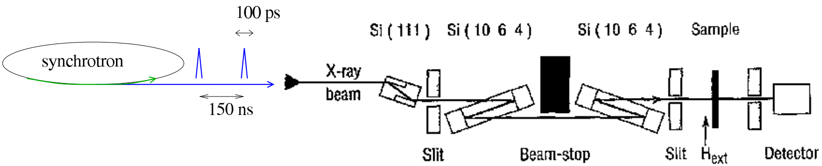
v. Bürck et al., PRB **46**, 6207-6211 (1992)





How this is measured on a synchrotron

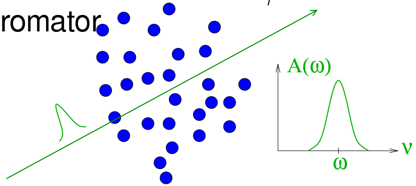
Using synchrotron radiation: pulsed, broadband source



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

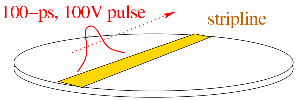
meV-resolving monochromator

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

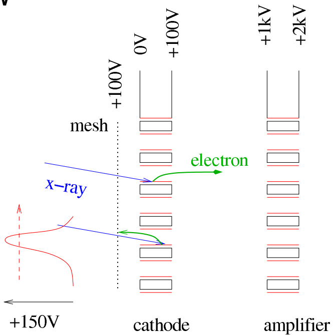


Gated MCP

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.,
Rev. Sci. Instrum. **62**, 124 (1990)

10^{-10} contrast possible?