LA-UR-21-32331

Approved for public release; distribution is unlimited.

Title:	Advanced X-ray Methods for PMI in MFE
Author(s):	Wang, Zhehui
Intended for:	Collaboration discussions Web
Issued:	2021-12-20

Advanced X-ray Methods

For PMI in MFE

Zhehui (Jeph) Wang for **UDA** collaboration

Los Alamos National Laboratory, Los Alamos, NM 87545

(email: zwang@lanl.gov)

UDA= Ultrafast Detectors & Applications

LANL Radiographic imaging

- X-rays, Gamma-rays
- Protons
- Muons
- Neutrons
- Electrons

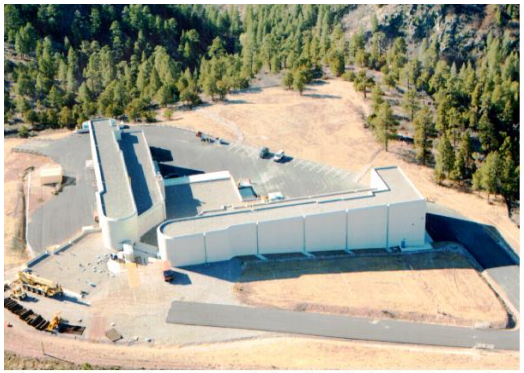
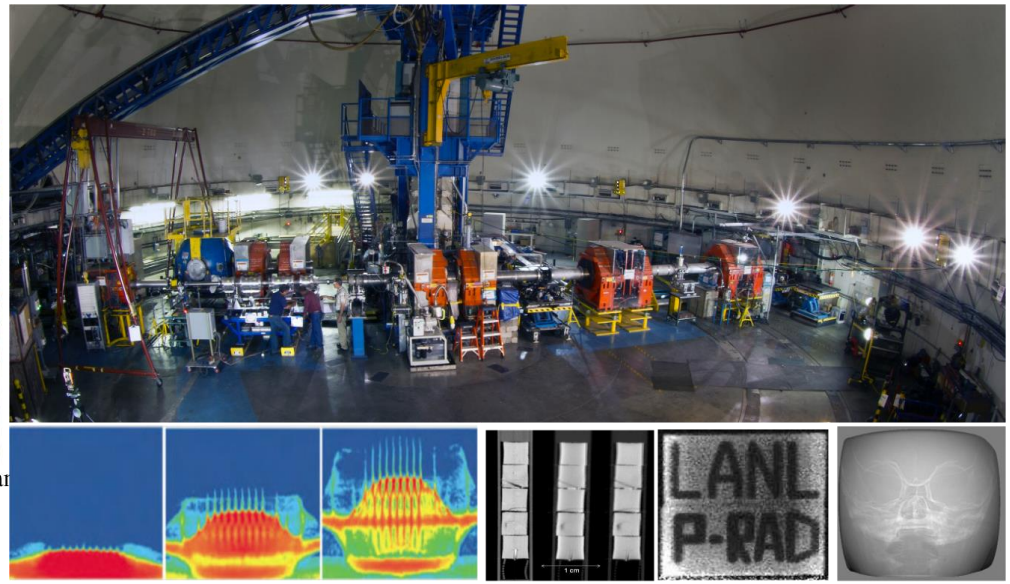
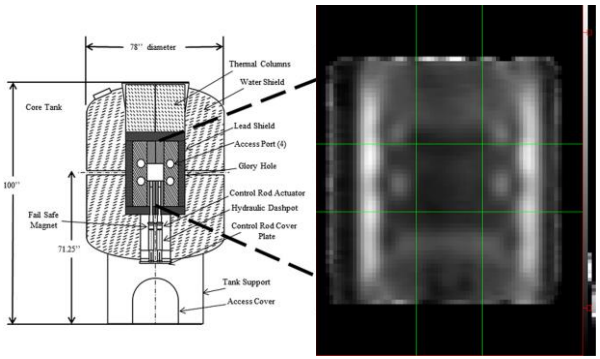
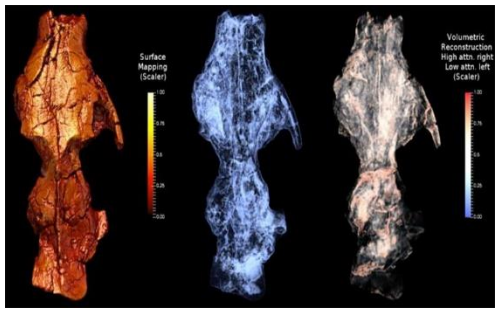


Figure 1. Aerial view of the Dual Axis Hydrodynar





Perry *et al* (2013)

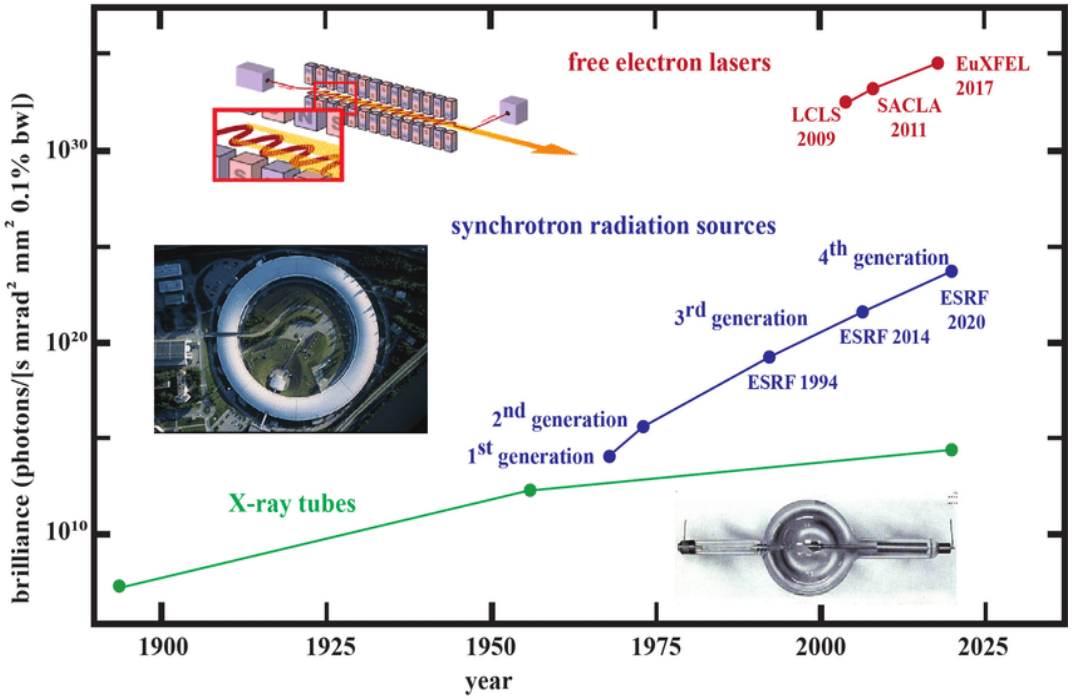


Nelson *et al* (2018)

Merrill *et al* (2018)

Physics & Technol. of Advanced X-ray imaging

- **X-Ray Sources**
  - Coherent vs incoherent
- **X-ray Imaging methods**
  - Propagation, Geometry and Optics
- **X-ray Detector, electronics physics, Noise**
- **Data Science & Methods**
- **Theory & Interpretation**
  - X-ray-interaction physics
  - Multi-scale multi-physics Simulations

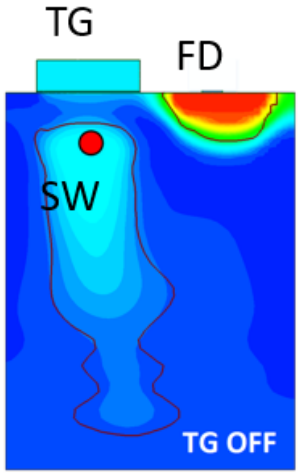


V. Cerantola et al, J. Phys. Cond. Matt. 33 (2021) 274003.

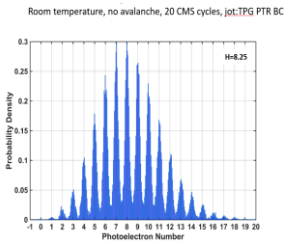
CMOS sensor designs down to pixels

DARTMOUTH

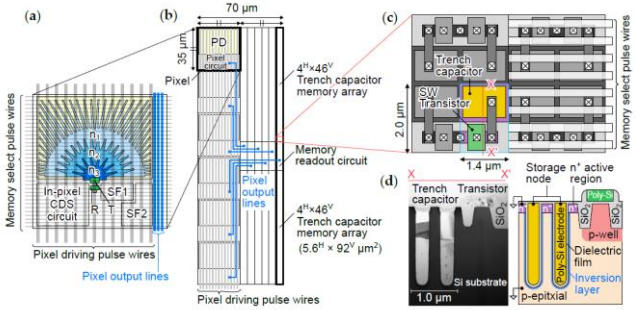
20-Mpixel SPDA



~0.2e$^-$ rms noise



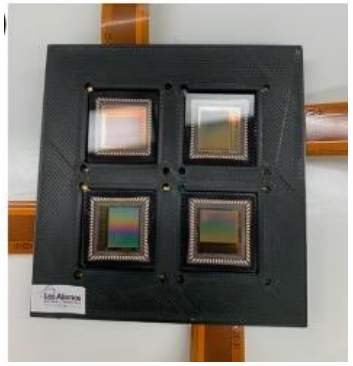
Quantized PE

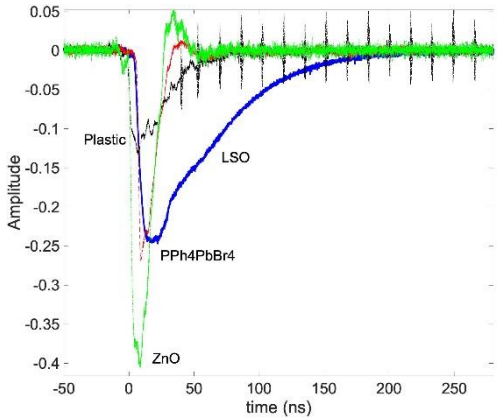


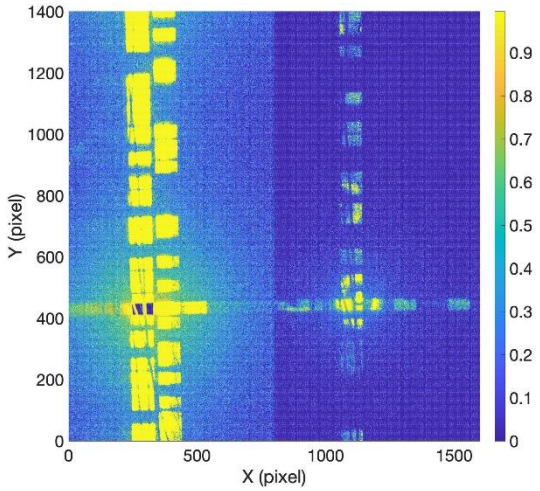
100 M fps+ capability

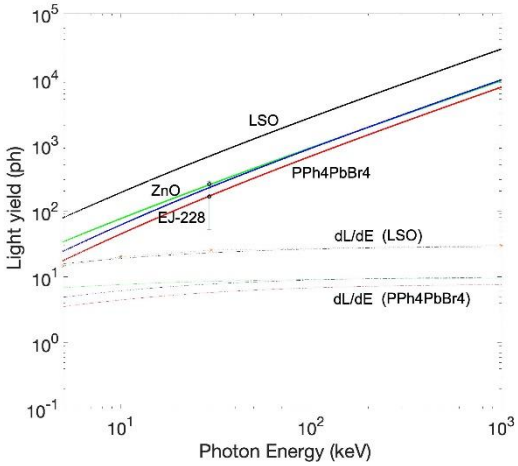
Suzuki et al, Sensor 20 (2020) 1086

Large FOV: Billion-pixel X-ray cameras (BiPC-X)



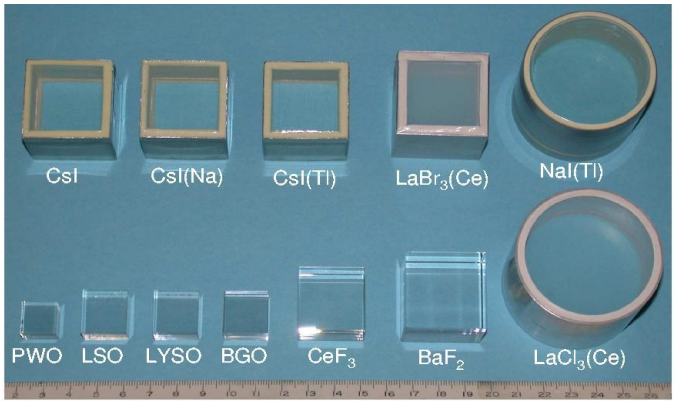




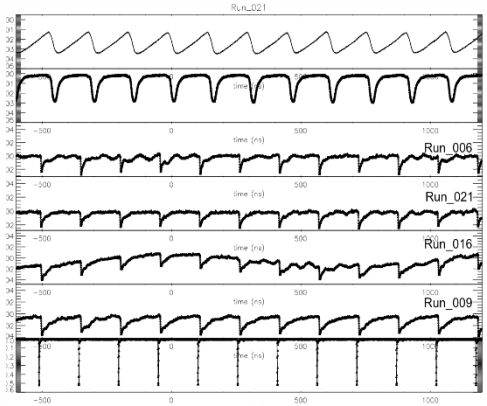


Wang *et al*, Rev. Sci. Instrum. 92 (2021) 043708

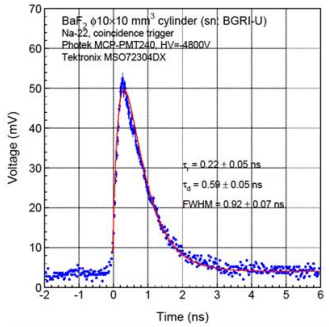
Multiple Fast Scintillator Candidates



	LYSO:Ce,Ca	ZnO:Ga	BaF_2:Y	YAP:Yb	LuAG:Ce	$LaBr_3$:Ce
Density (g/cm^3)	7.4	5.67	4.89	5.35	6.76	5.29
Melting Points (^oC)	2050	1975	1280	1870	2060	783
X_0 (cm)	1.14	2.51	2.03	2.77	1.45	1.88
R_M (cm)	2.07	2.28	3.1	2.4	2.15	2.85
λ_I (cm)	20.9	22.2	30.7	22.4	20.6	30.4
Z_{eff}	64.8	27.7	51.6	31.9	60.3	45.6
dE/dX (MeV/cm)	9.55	8.42	6.52	8.05	9.22	6.9
λ_{peak} [a] (nm)	420	380	300 220	350	520	360
Refractive Index[b]	1.82	2.1	1.5	1.96	1.84	1.9
Normalized Light Yield[a,c]	100	6.6[e]	1.7 4.8	0.19[e]	35[f] 48[f]	153
Total Light Yield (ph/MeV)	30,000	2,000[e]	2,000	57[e]	25,000[f]	46,000
Decay Time[a] (ns)	40	<1	600 0.5	1.5	820 50	16
Light Yield in 1st ns (photons/MeV)	740	610[e]	1200	28[e]	240	2,200
40 keV Att. Length (1/e, mm)	0.185	0.407	0.106	0.314	0.251	0.131



LYSO + PMT 1
Fast plastic + PMT 2
Diamond (Quadrant A)
Diamond (Quadrant B)
Diamond (Quadrant C)
Diamond (Quadrant D)
APS timing pulses

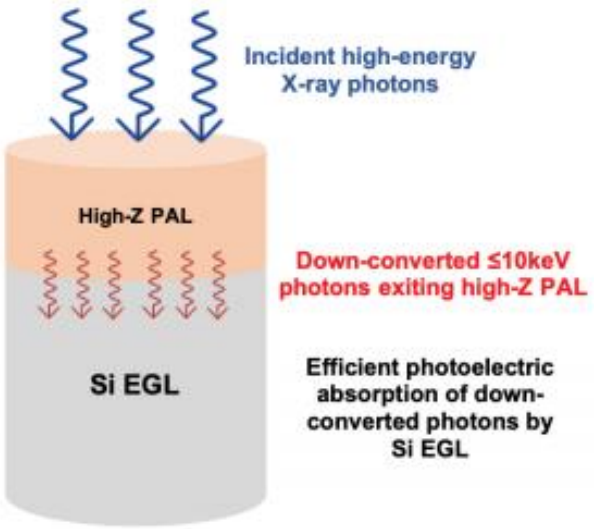


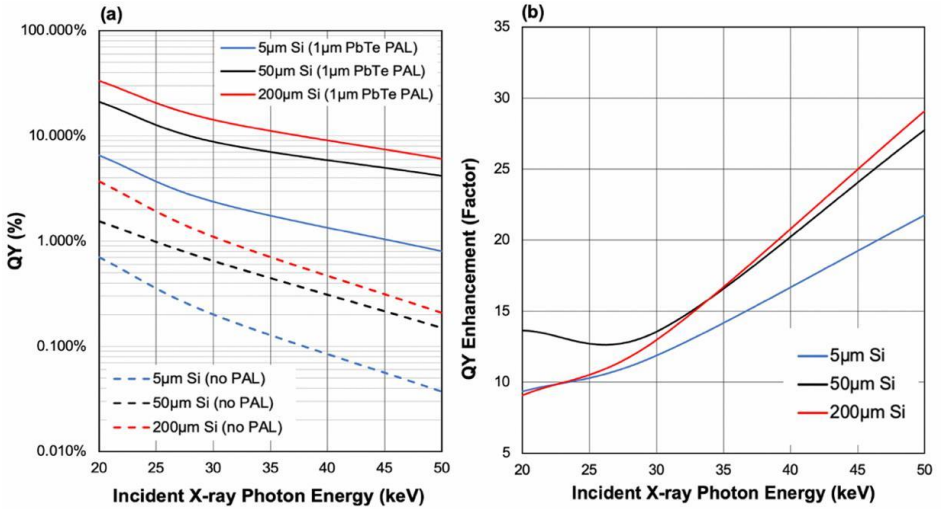
Xie *et al*, NIMA 927 (2019) 287

Hu *et al*, NIMA 950 (2020) 162767

PAL layer integration with CMOS sensor

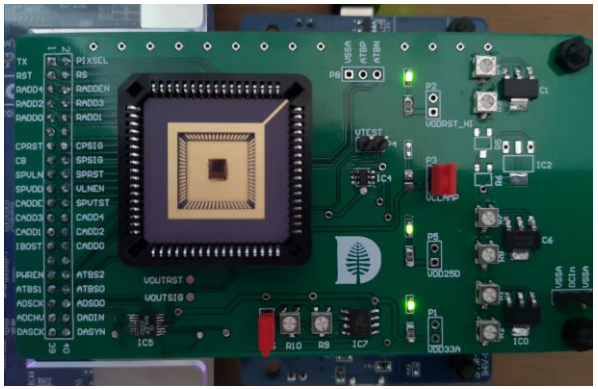
DARTMOUTH





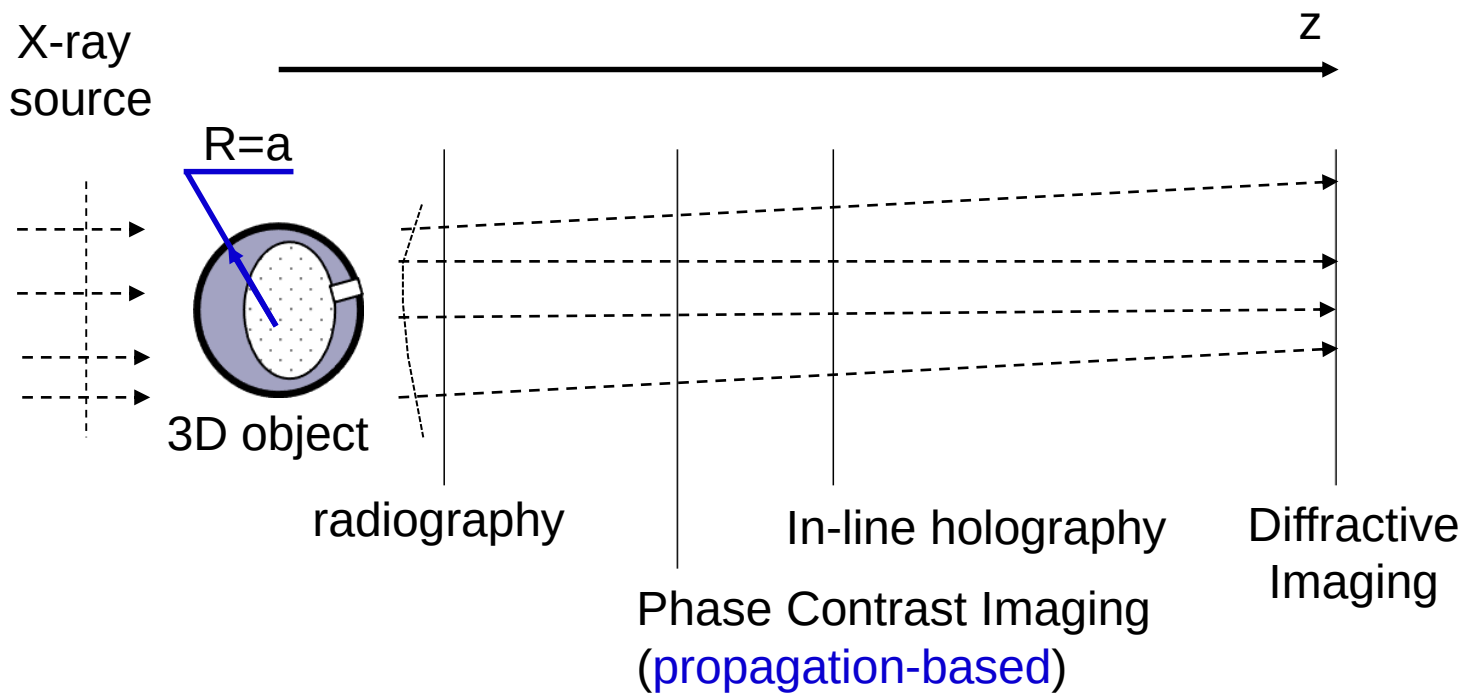
Pixel-level hybridization

Lee *et al*, Instruments 5 (2021) 17

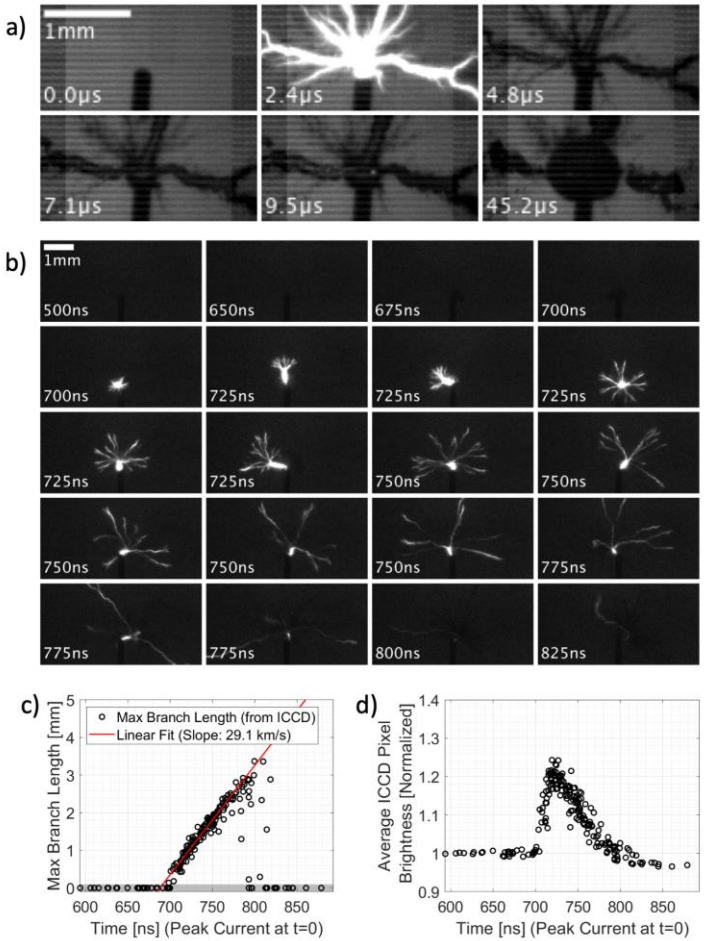


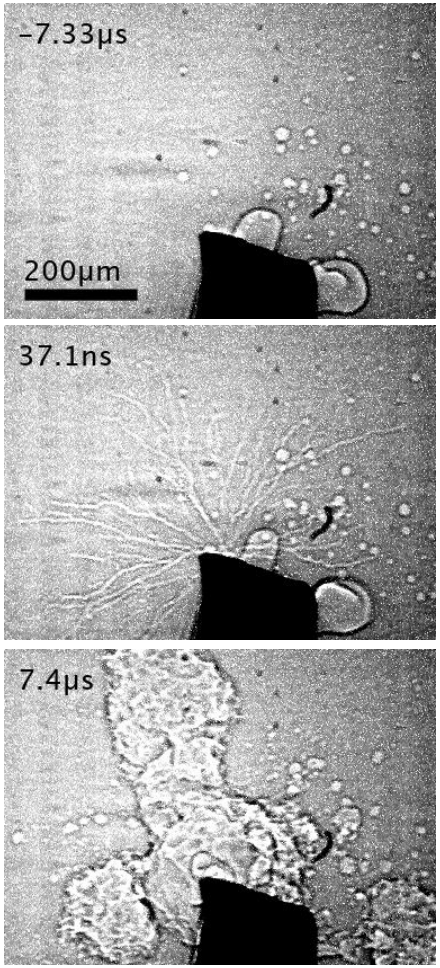
Yue et al, (2021)

Geometries of Advanced X-ray imaging



Ultrafast lightning in water

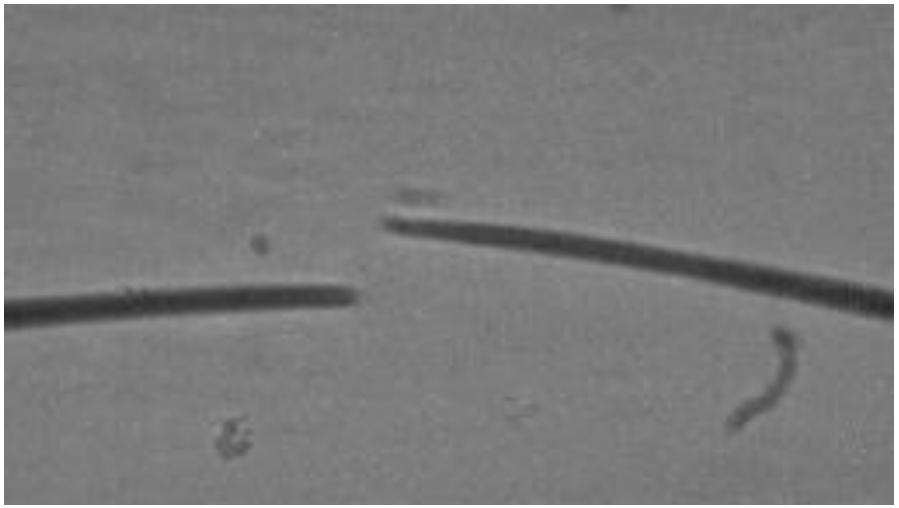




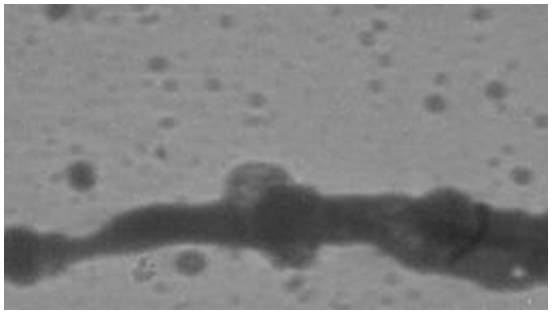
'ultrafast lightning in H_2O'

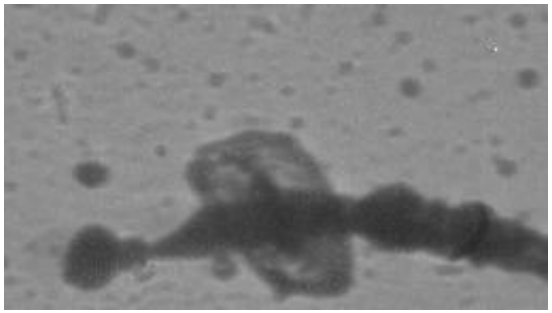
Campbell *et al*, Phys. Rev. Res. 3 (2021) L022021

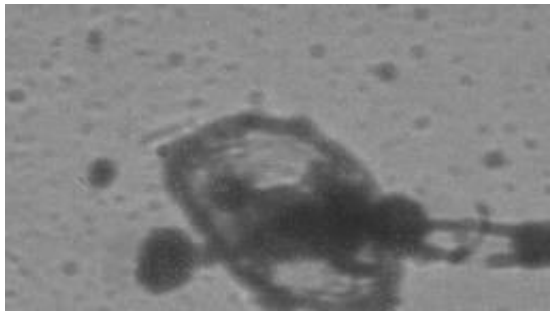
In need of 3D information: X-ray experiment @ APS



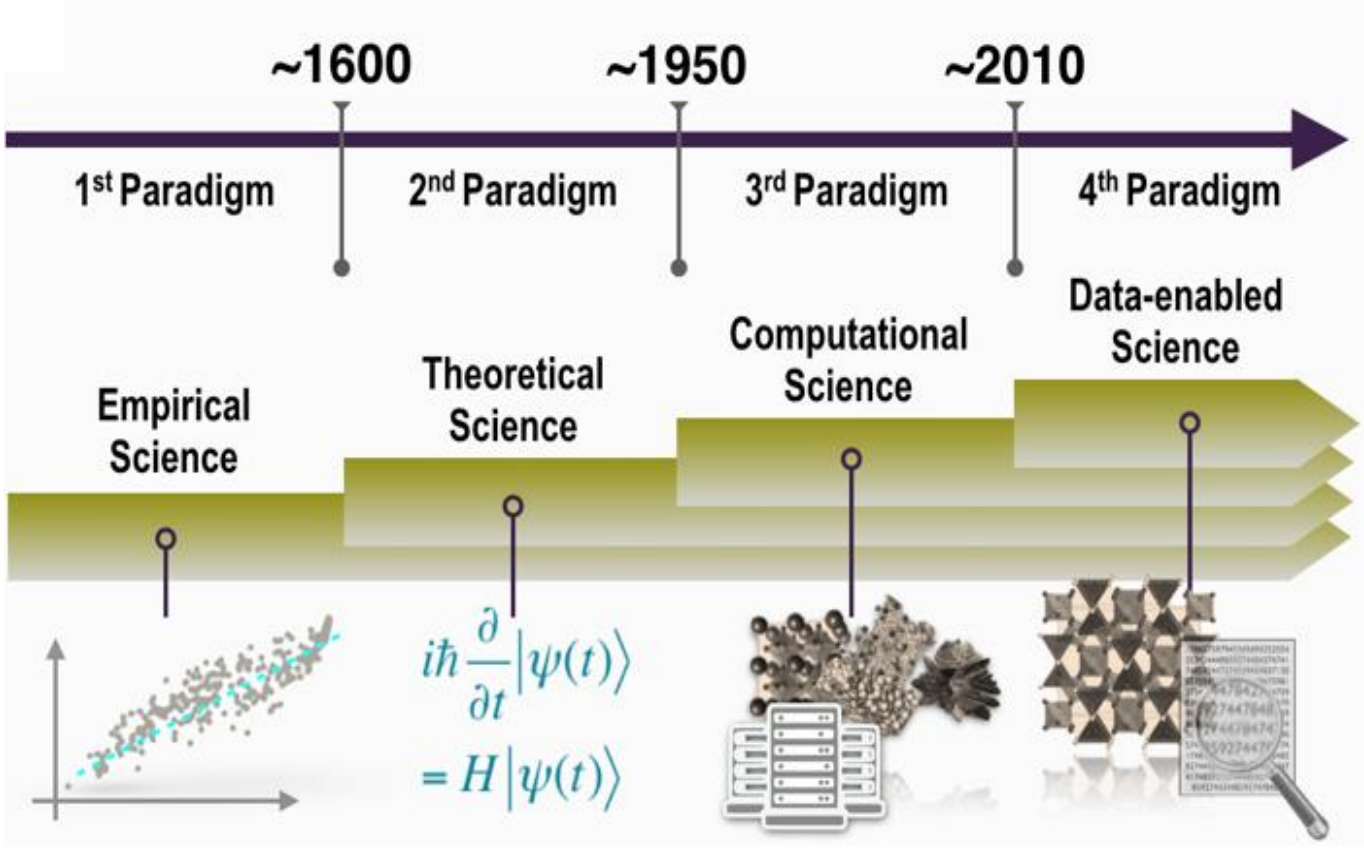
~ 100 kfps







Why ML?



Pilania *et al*, J Mat. Sci 54 (2019) 8361

What ML can do?

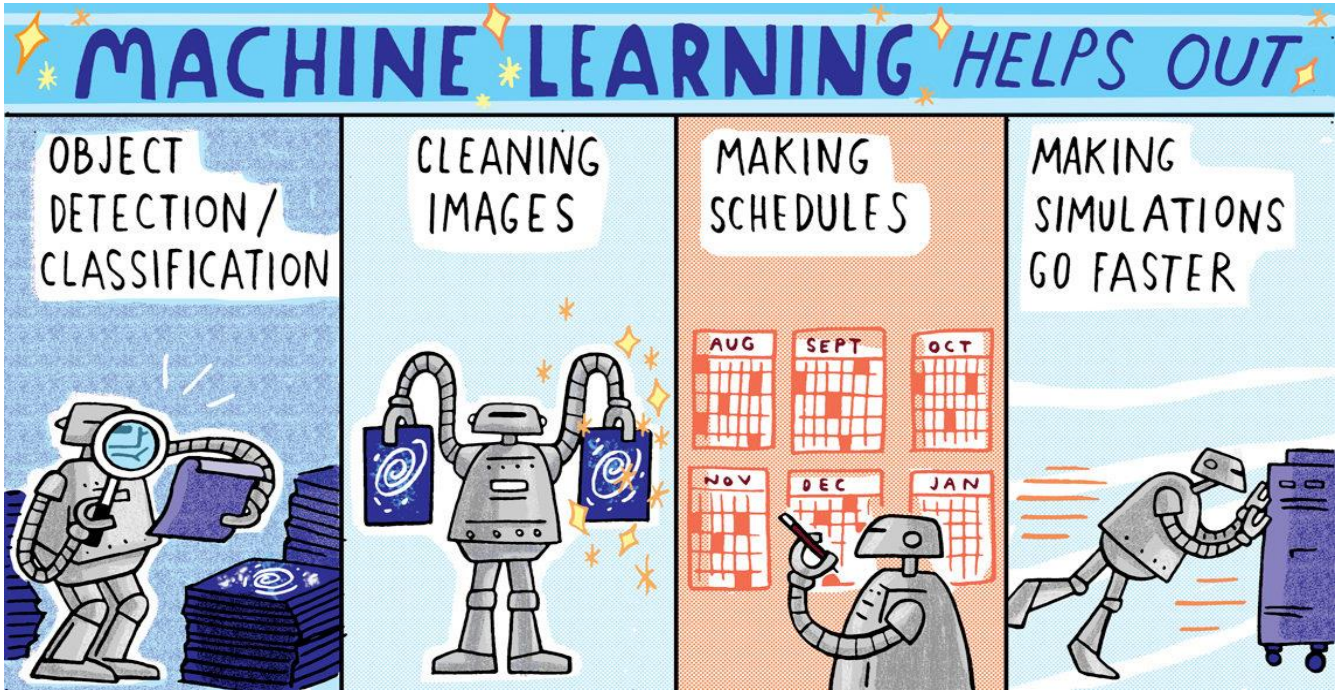
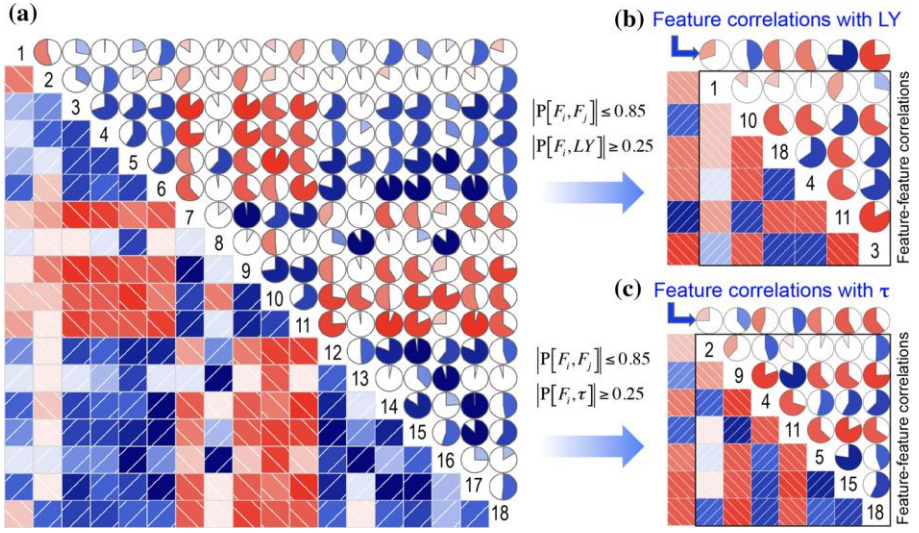
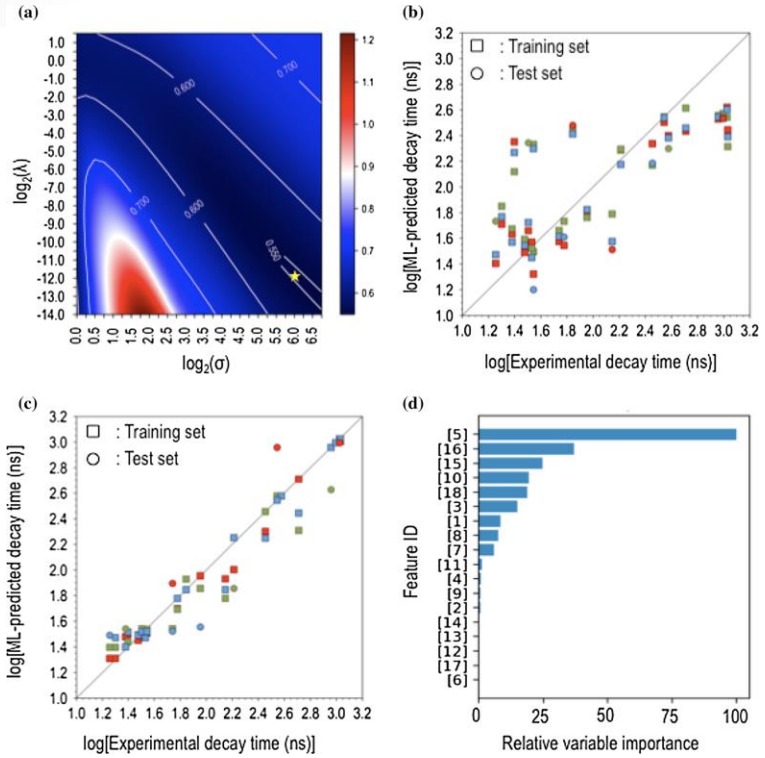


Illustration by Sandbox Studio, Chicago with Corinne Mucha

Using Physics-informed ML for scintillator discovery

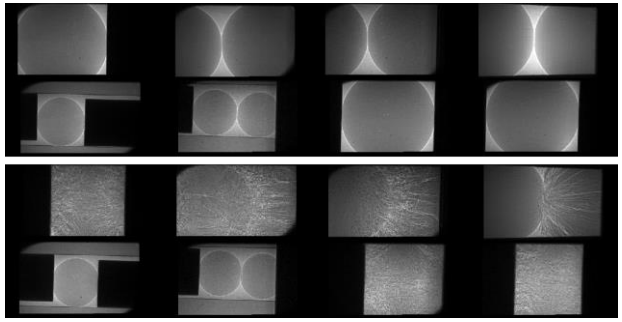
DFT Computations: Costly and slow



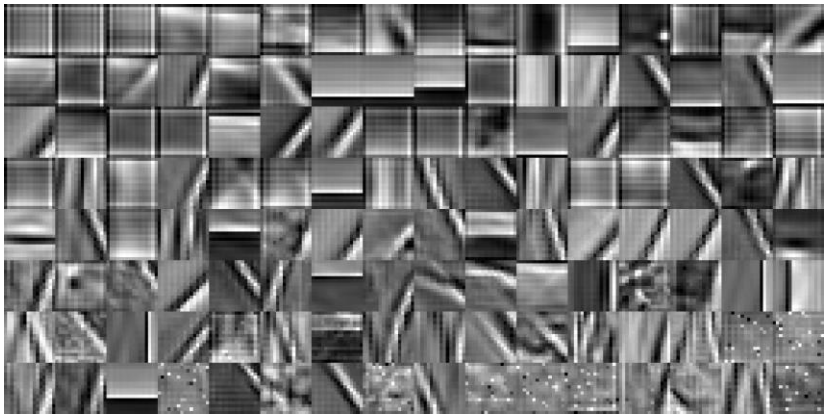


Pilania *et al*, J Mat. Sci 54 (2019) 8361

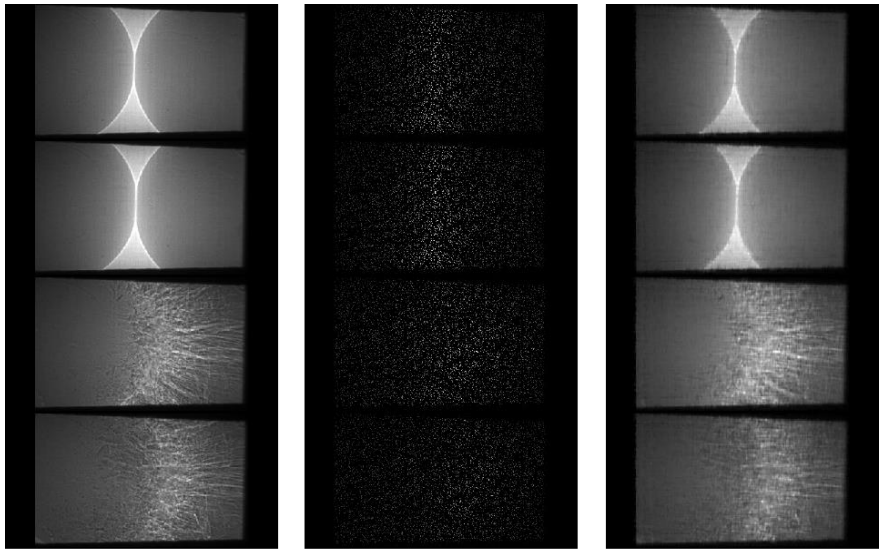
Implementation of Sparse imaging principle



Experiments



Feature extraction

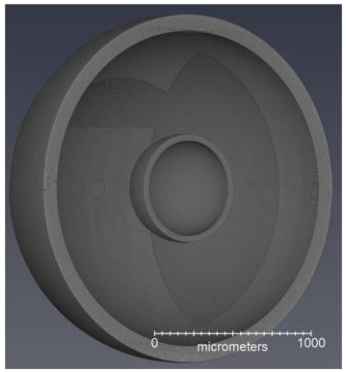


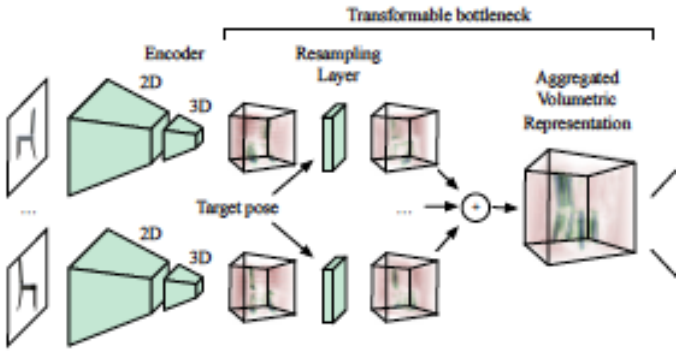
(a) (b) (c)

Validation

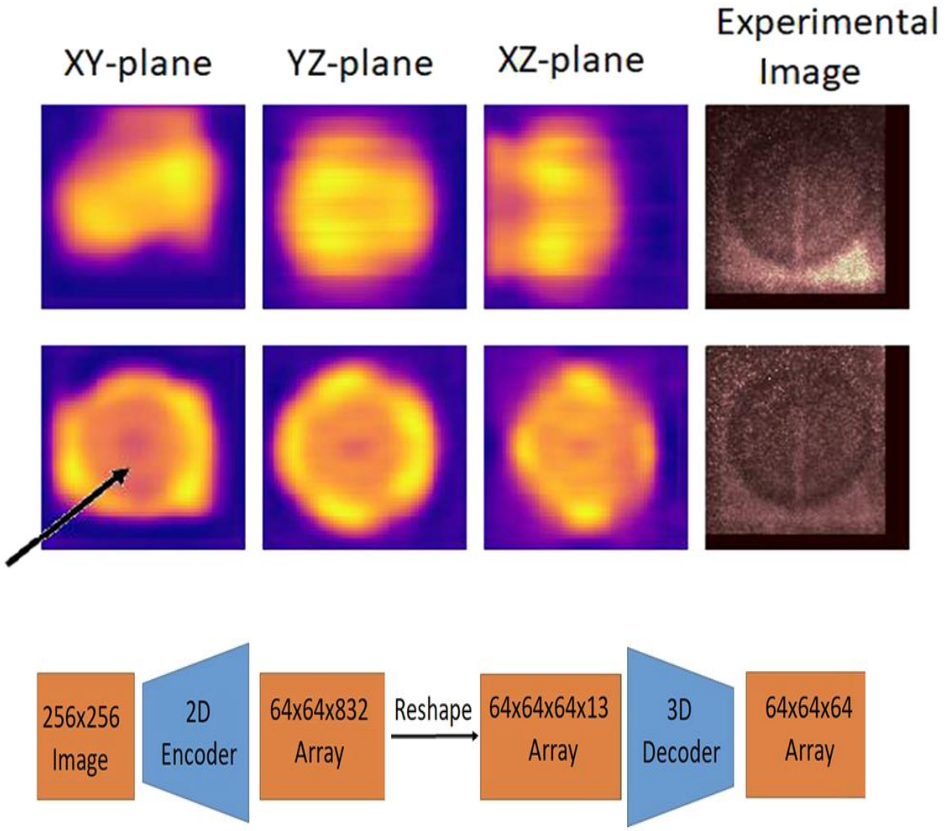
Wang, Iaroshenko, *et al*, JINST 13 (2018) C01035

3D reconstruction example



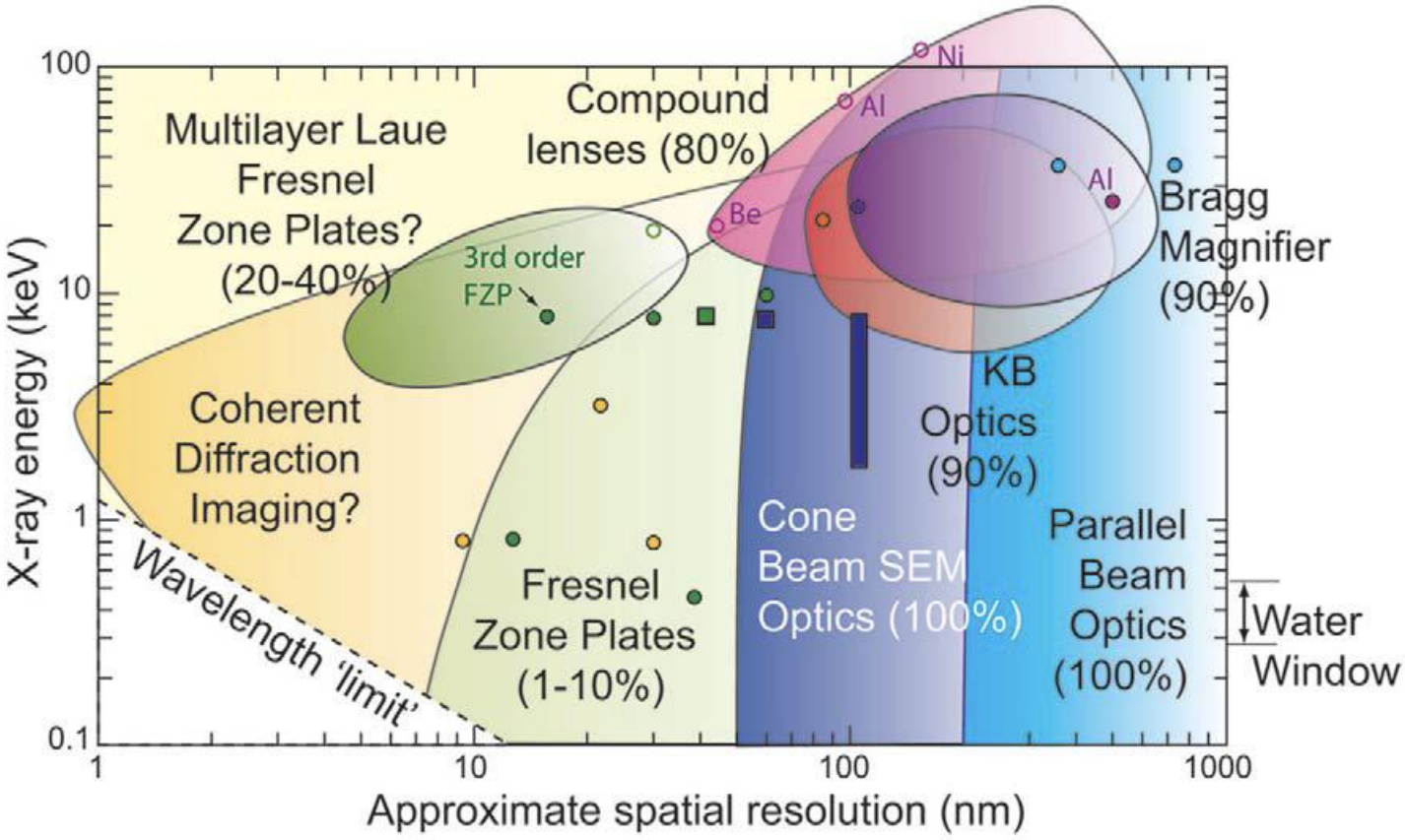


Olszewski *et al*, (2019)



Wolfe *et al*, Rev. Sci. Instrum 92 (2021) 033547

Sub-micron resolutions



Withers (2007)

Summary

- **Flash X-ray radiography (WWII)**
  - With Roots in Flash photography
- **Recent trends** (hard-ware driven)
  - Increasing number of probes (protons, neutrons, muons, …)
  - CMOS technology & device physics (legacy of the Moore's law)
  - Material discoveries (scintillators)
  - Hybrid approach (PAL concept)
- **Emergent opportunities** (data-driven)
  - data science, machine learning
  - New applications for PMI