Introduction of a single shot electron bunch charge monitor with organic EO Pockels crystals

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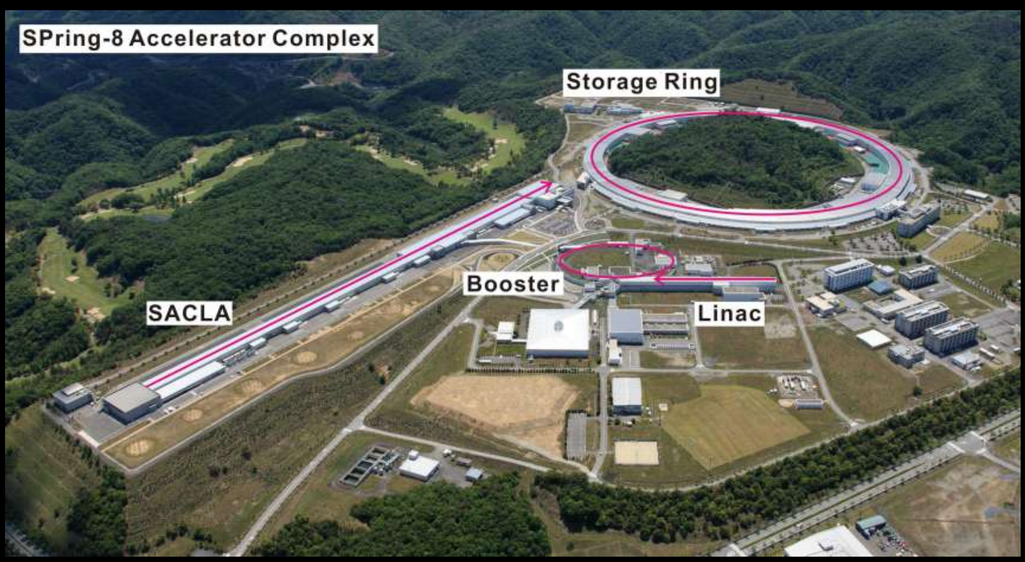
Introduction



Electron bunch param. (sliced)	
Energy	8 GeV
Beam size	40 um (rms)
Bunch duration	40 fs (FWHM)
Charge	100 pC
Emittance	0.7-1 π mm･mrad
Peak current	~3 kA

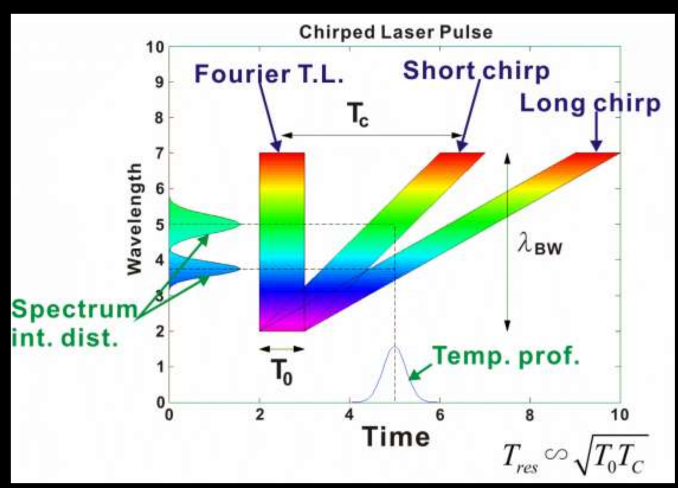
SACLA (SPring-8 Angstrom Compact free electron Laser)
* Construction completed, user operation is scheduled to start in FY2011.
* Highly compressed electron bunch required [1]
→ Non-destructive & real time bunch monitor required

We introduce…
"3D bunch charge distribution monitor (3D-BCD monitor)"

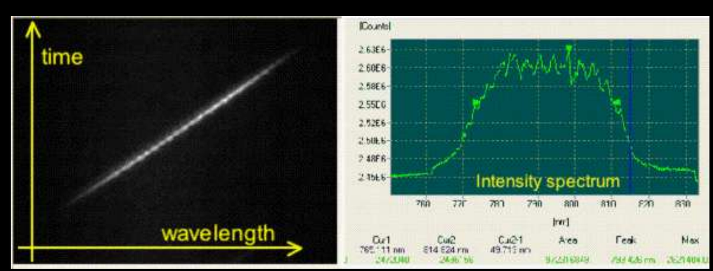
1) Non-destructive
→ based on EO method [2]

2) Single shot
→ spectral decoding
w/ multi-ch. spectrometer

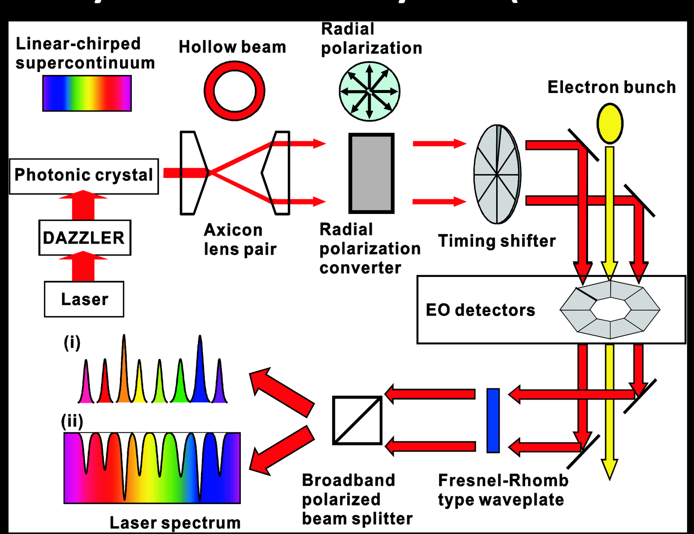
3) Real time
→ rectangular spectrum
& linearly chirped probe laser

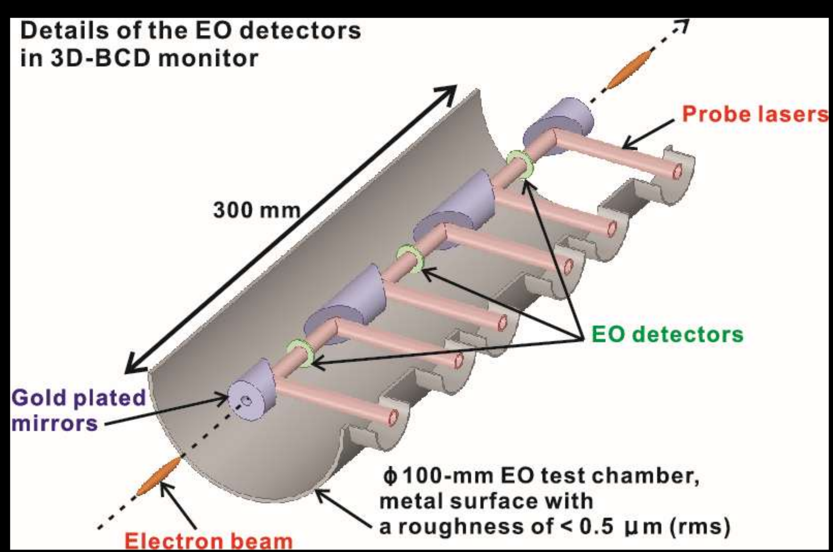


4) High temporal resolution (< 30 fs [FWHM])
→ > 400 nm bandwidth
w/ organic EO crystals (ultra-fast response)

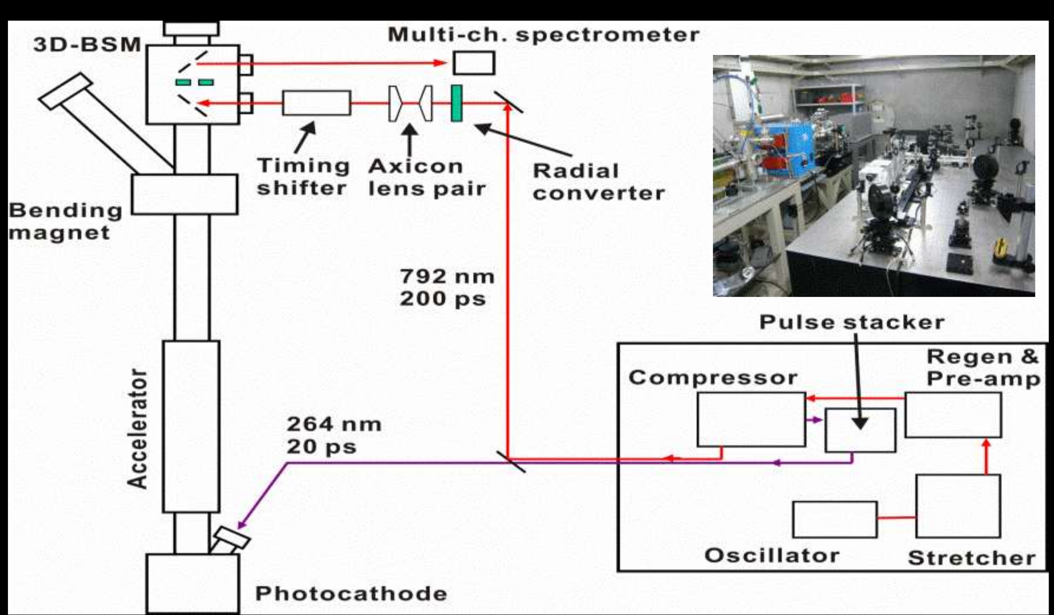


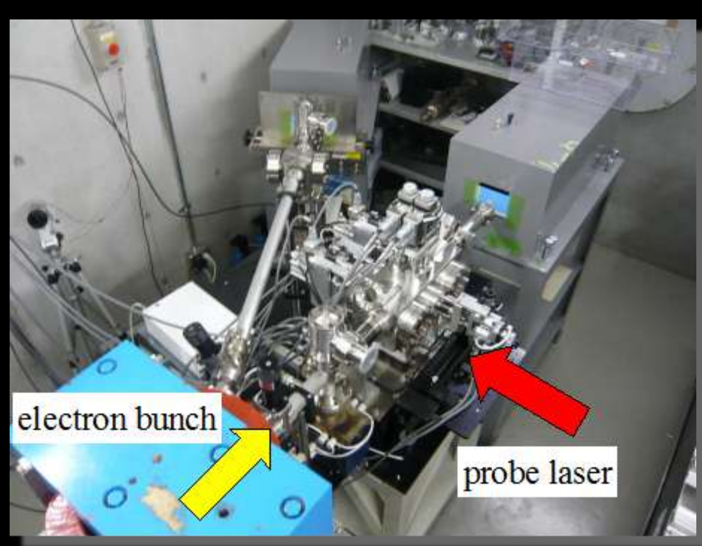
5) 3D bunch charge distribution monitor
w/ high resolution (longitudinal)
→ radially polarized hollow laser
& radially allocated EO crystals (transverse)



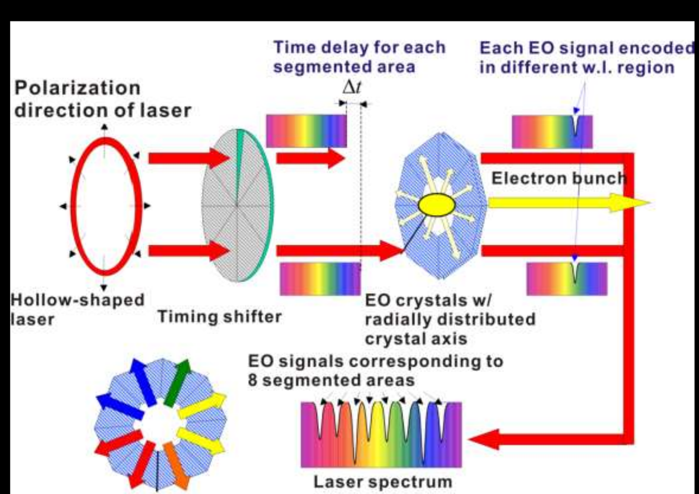


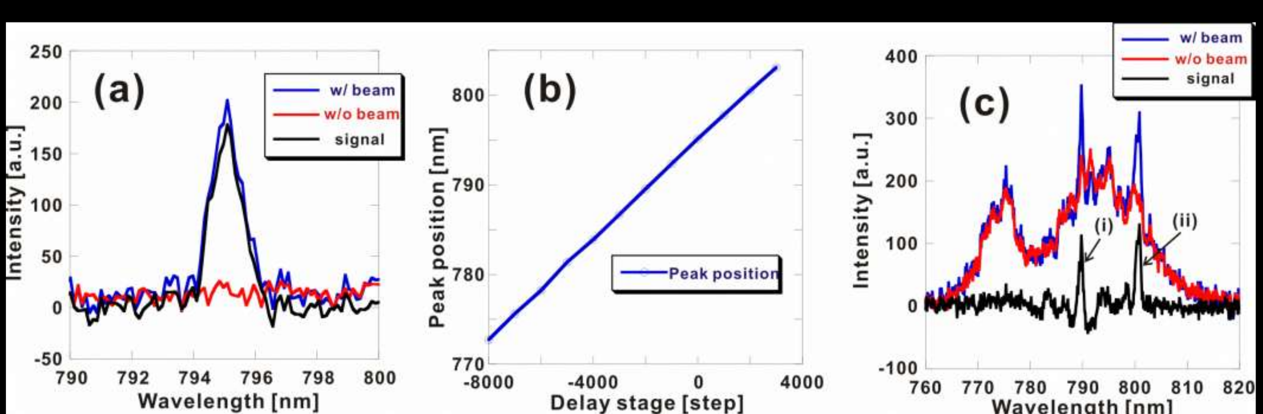
Feasibility test @ SPring-8 photoinjector test facility, 2010





Beam Energy	25 MeV
Beam size	100 um (rms)
Bunch duration	6 – 10 ps (FWHM)
Charge	1.5 nC
EO crystal	ZnTe x 2 ; 10 x 10 x 1 mm³ (4 mm from e- beam axis)
Laser bandwidth	775 – 795 nm
Laser pulse width	200 ps (FWHM)





(a) EO signal @ laser incident RF phase ϕ = 80 deg (sine func.)
(b) Chirp linearity of the probe laser
(c) EO signals probed 2 ZnTe crystals simultaneously

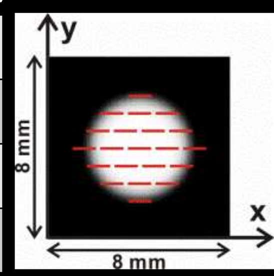
- Chirp linearity scan gave 9.58 ps / nm conversion factor.
- Staggered double signal peak observed thru the timing shifter.
- 10.8 ps (FWHM) electron bunch width measured.

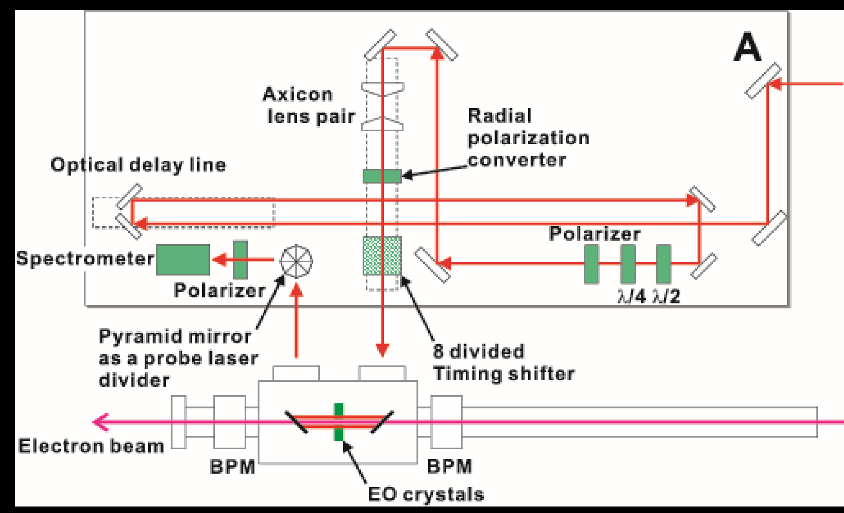
3D-BCD monitor w/ radial polarized & hollow-shaped probe laser verified to work

Numerical feasibility study for optical setup

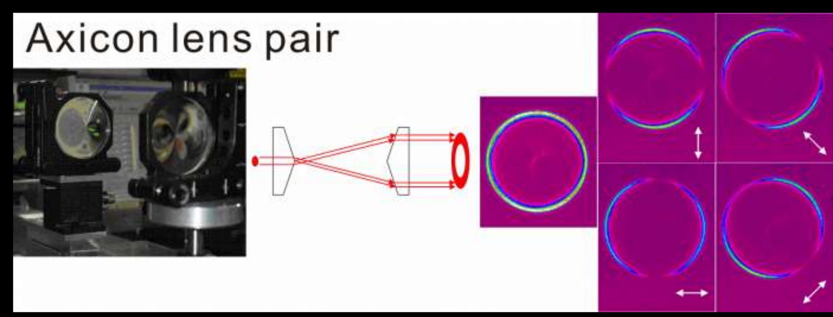
Calc. condition (input laser specs):

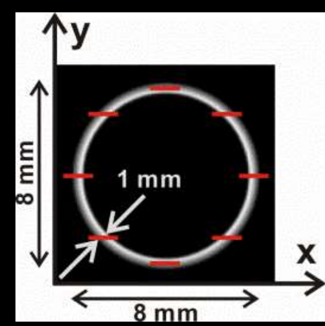
Laser size	ϕ2 mm [FWHM]
Bandwidth	775 – 795 nm
Polarization	linear
Pulse duration	200 ps (FWHM)

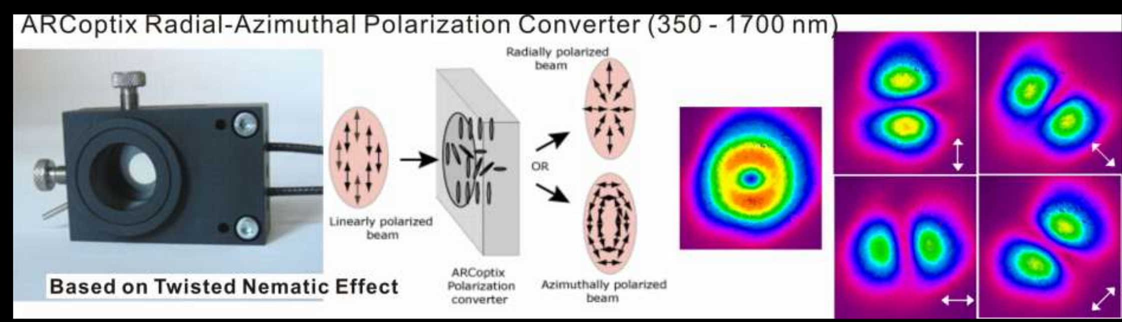


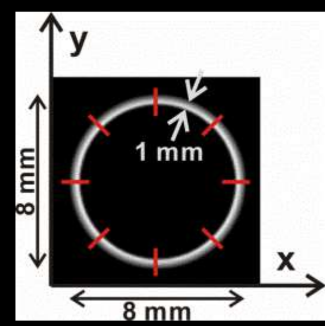


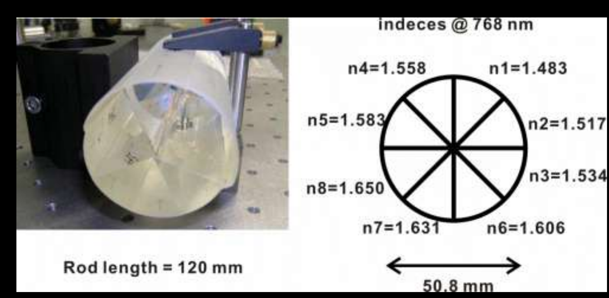
- Laser propagates actual transport path length ~20 m.
- Focal length of axicon lens pair adjusted to be 35 mm to obtain ϕ8 mm hollow shape.

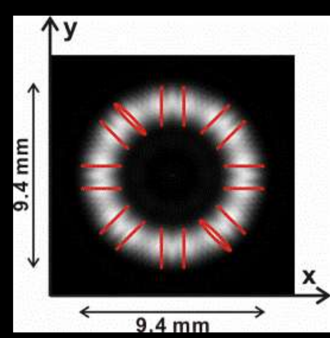


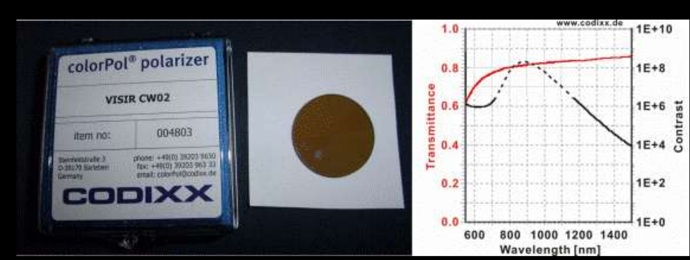


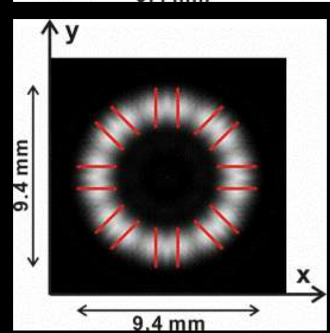








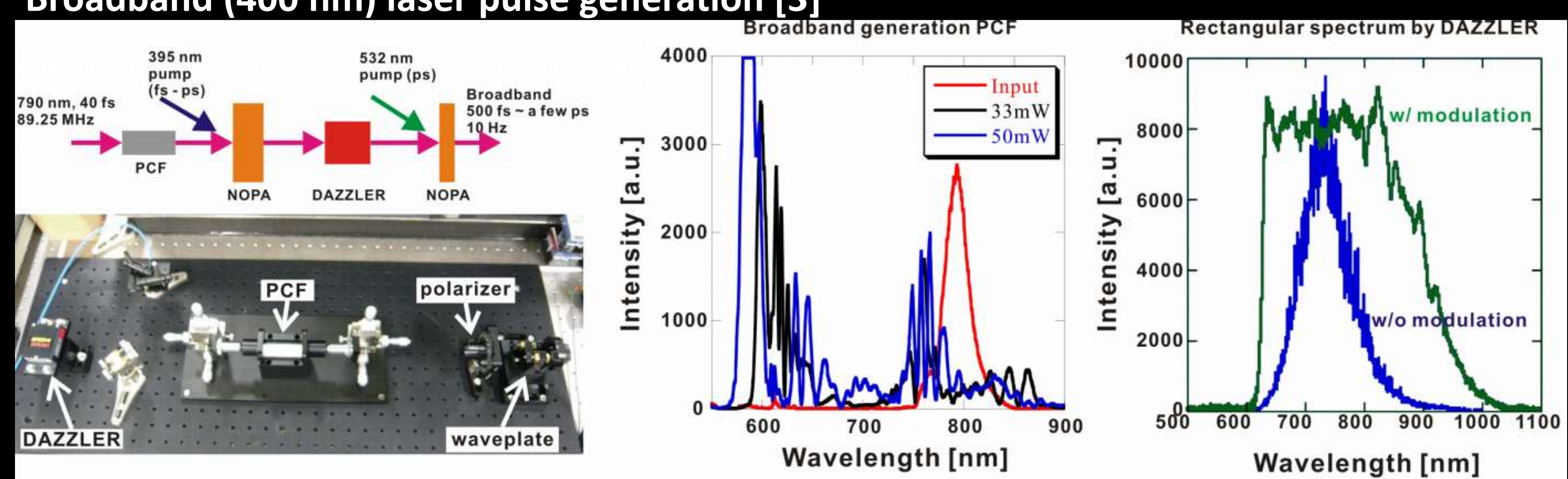




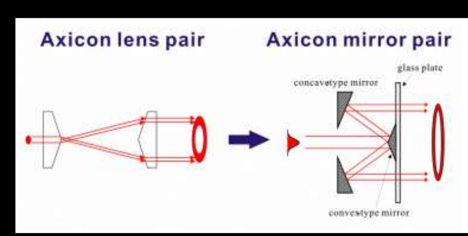
Radial polarization numerically obtained and confirmed @ entrance of the EO crystals.

Toward 30 fs temporal resolution

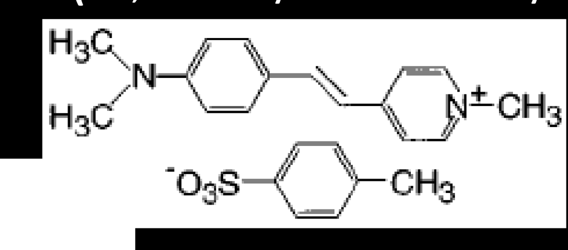
1. Broadband (400 nm) laser pulse generation [3]

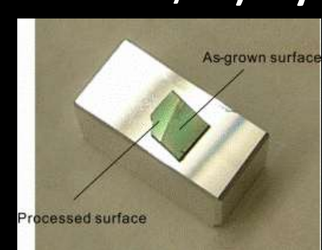


1) Broadband laser by PCF (Photonic Crystal Fiber)
2) Broadband amplification w/ NOPA (SHG of Ti:Sa & YAG)
3) Higher dispersion control w/ DAZZLER and NOPA
4) Axicon lens → Axicon mirror



2. Organic EO crystals for ultra-fast response in wider THz region
For example, DAST (4-N, N-dimethylamino-4'-N'-methyl-stibazolium-tosylate) crystal [4] :

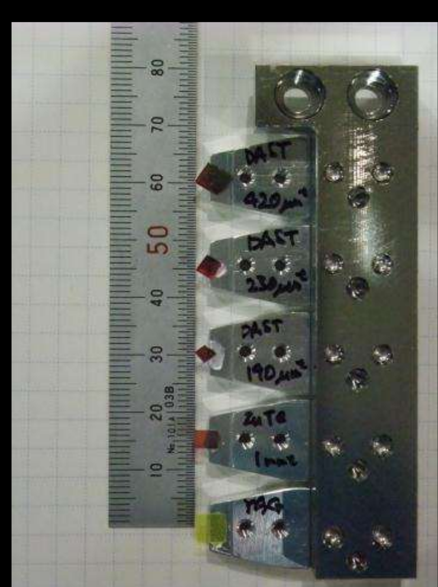


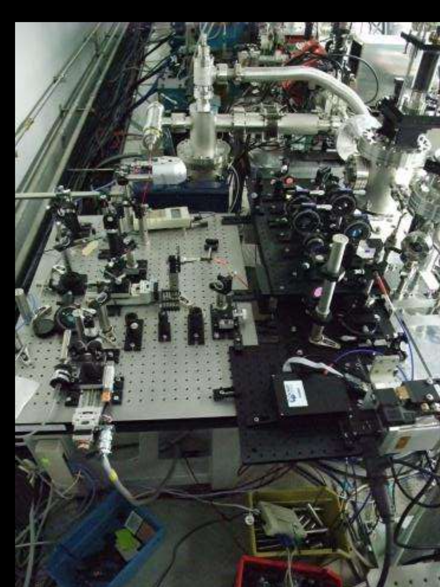


High qualified DAST collaborated w/ H. Minamide (RIKEN)

Feasibility experiment scheduled in SCSS accelerator, SPring-8 on Feb. 2012.

Wavelength	49 nm
e⁻ beam energy	250 MeV
Bunch charge	0.25 nC
Bunch length	300 fs (FWHM)
Peak current	> 300 A





References

[1] H. Tanaka, T. Hara and T. Togawa, private communication
[2] H. Tomizawa et al., in Proceedings of FEL2007, Novosibirsk, Russia, (2007) 472
[3] S. Matsubara et al., in Proceedings of FEL2009, Liverpool, UK. (2009) 269
[4] F. Pan et al., Appl. Phys. Lett. 69 (1996) 13