Acousto-optic Modulator (AOM) as Laser Pulse Picker

First Experiences at PITZ

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AOM as Pulse Picker
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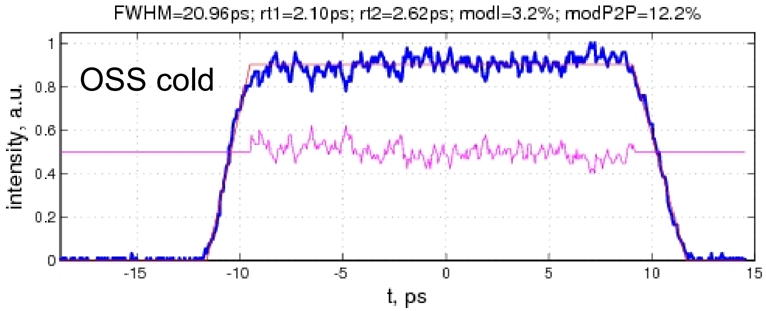
Contents

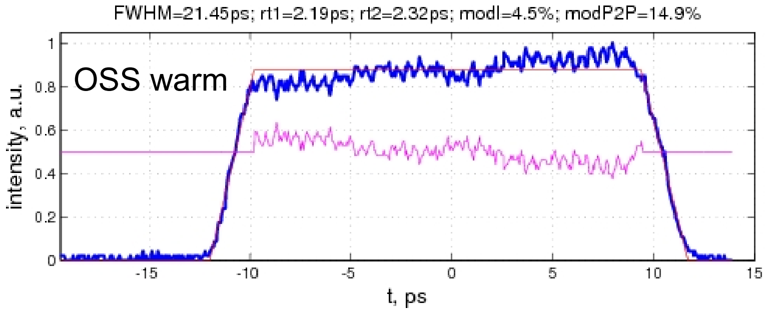
Motivation

- Critical part of photocathode laser system: frequency quadrupling. Wavelength of laser pulses is converted from infrared to ultraviolet (at PITZ: 1030nm → 257.5nm) in two steps with nonlinear crystals – LBO and BBO
- BBO crystal (2nd step – 515nm → 257.5nm) absorbs a tiny fraction of UV light – significantly enough that effects have been seen at PITZ and FLASH
  - Absorption leads to local increase of temperature which changes the properties of the frequency conversion
- PITZ
  - Difference of "cold OSS" and "warm OSS"
  - Variations of bunch charge over pulse train
- FLASH
  - Variation of beam arrival time over pulse train

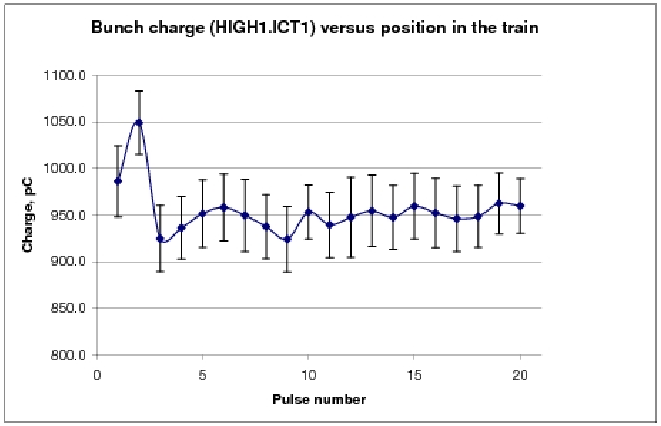
Experimental Evidences for BBO Crystal Warming at PITZ

- OSS: Difference of pulse length and form directly after starting and after waiting a few minutes (measured 05.05.2011M)



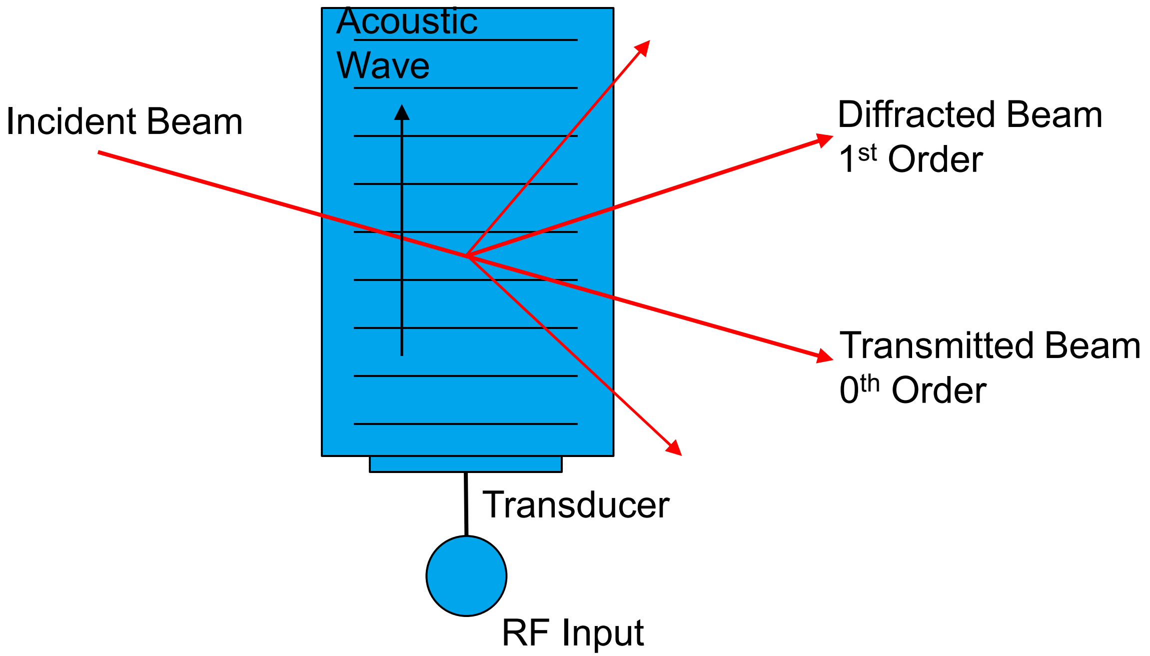


- Bunch charge along pulse train (measured 04.05.2011M)



The Acousto-Optic Modulator (AOM)

- Possible solution: cw pulse train conversion into UV, then definition of pulse trains with UV pulse picker → stable temperature of BBO crystal
  - Important: pulse picker must not show same affect as BBO crystal!
- Candidate for pulse picker: Acousto-Optic Modulator (AOM)
  - Principle: Diffraction of laser beam at acoustic wave



Comparison of available AOMs

	Crystal Technologies via EQ Photonics: 3200-1220	A-A Optoelectronics via Pegasus Optik: MQ200-B30A1.5-244.266-Br	Gooch & Housego: 35110-2-244-BR (APE: OA99)	Brimrose via Laser2000: FSPP-250-16-BR-257
Material	SiO_2 (Quartz)	SiO_2 (UV grade fused silica)	SiO_2 (KrF grade fused silica)	SiO_2 (UV grade fused silica)
Wavelength	257nm	244-266nm	244-260nm	257nm
Aperture	0.25mm diameter	1.5mm x 2mm	2mm diameter	0.3mm diameter
Center Frequency	200MHz	200MHz	110MHz	250MHz
Rise time (10%-90%)	143ns/mm beam diameter	110ns/mm beam diameter 10ns min.	110ns/mm beam diameter 10 ns min.	34nm min.
Contrast ratio DC	1000:1	2000:1	1000:1	>1000:1
Contrast ratio 1MHz	same	same	same	? (same)
Diffraction efficiency	75%	>70% over range >85% @ 257nm	>70%	50%
Insertion loss	<5%	<5%	<1%	<2%
Geometry	Orthogonal (with AR coating)	Brewster incidence (uncoated)	Brewster incidence (uncoated)	Brewster incidence (uncoated)
Deflection angle	9mrad	8mrad	4.7mrad	10mrad
Max. power density	?	> $10W/mm^2$	> $10W/mm^2$	$100W/mm^2$
Wavefront distortion	?	$<\lambda/12$(est.)	- optical polishing	$\lambda/10$
Max RF power	1W	4W	4W	2W
V.S.W.R	1.5:1	1.5:1	1.2:1	2:1
Driver electronics input for pulse trains	TTL	Analog or TTL	TTL	1V @ 50Ω
Price AOM Driver Total	1400€ 820€ 2220€ (is 50% with report)	1998€ 4004€ 6002€	\$2600 =1820€ \$900 =630€ \$3500 =2450€ APE: 6613,43€	2690€ 3590€ 6280€

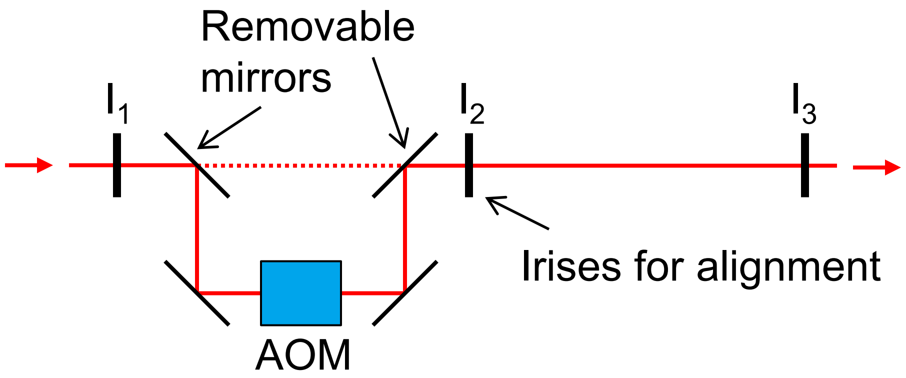
- Gooch&Housego AOM was bought in August 2011 (funded by FLASH)

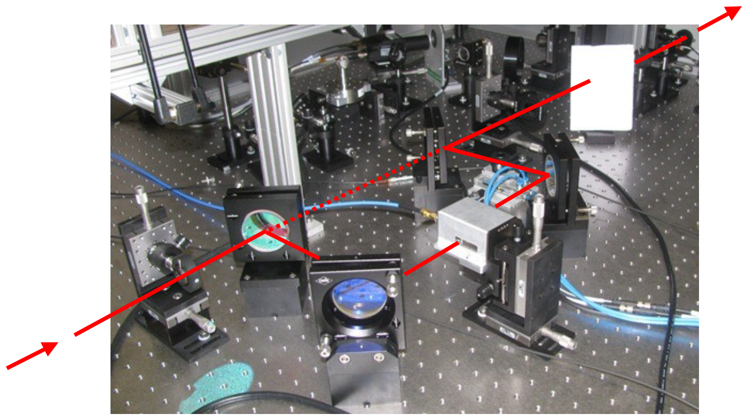
Some Checks

- Used beam: 1st order (highest contrast – ideally no power with RF off)
  - Total loss: (1 – insertion loss) * diffraction efficiency → around 20% at 257nm
- 1st order is frequency shifted
  - $\Delta\lambda = \frac{\lambda}{c}\Delta$ Δf : Center frequency (110MHz) → $\Delta\lambda$ < 0.1pm – negligible
- Progress of acoustic wave front during pulse duration (20 ps)
  - 0.12µm << beam diameter (1mm) → optical pulse sees essentially fixed reflector
- Pointing stability
  - $\Delta\Theta \approx \lambda \frac{\Lambda}{V_a}$ Δf : Frequency uncertainty; V_a: acoustic velocity (≈6000m/s for SiO_2)
    ↳ e.g. 1Hz → $\Delta\Theta \approx 5 \cdot 10^{-11}$ rad (1nm at 20m distance) – negligible
- Separation of diffraction orders
  - Angular separation: Equation as above with Δf : Center frequency (110MHz)
  - Distance to spatial separation of 0th and 1st order by 5mm: ≈2.10m

AOM setup at PITZ

- From Gooch & Housego: AOM + Driver + stage
- Guido Klemz: Buildup of electronic box including driver and interface to PITZ laser, e.g. trigger for synchronization
- Optical setup on laser table (switchable AOM mode)

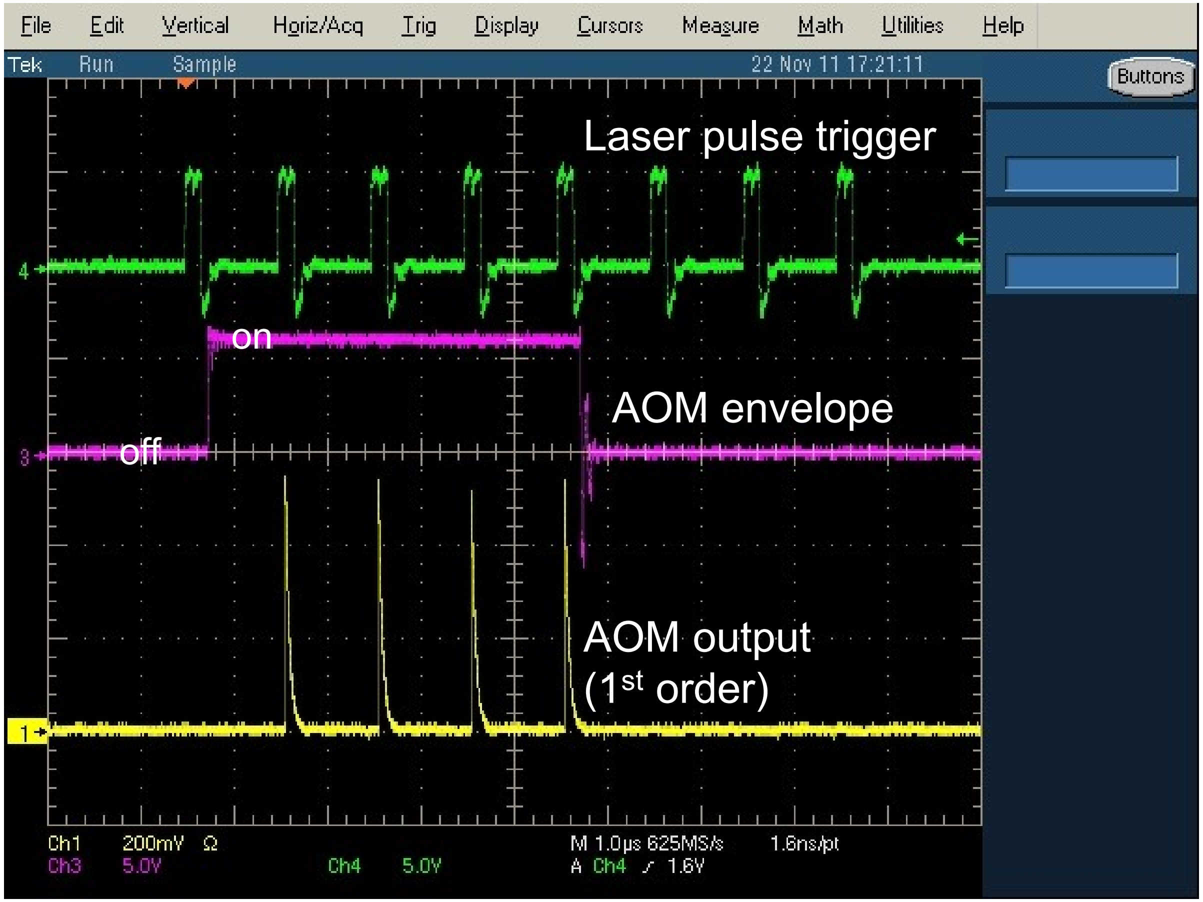




First Results (1)

> Electronics: Currently 2 standard modes

- AOM on when laser pulses present
- AOM envelope adjustable



> Fast switching – pulse to pulse

> High contrast ratio (at least 500:1)

First Results (2)

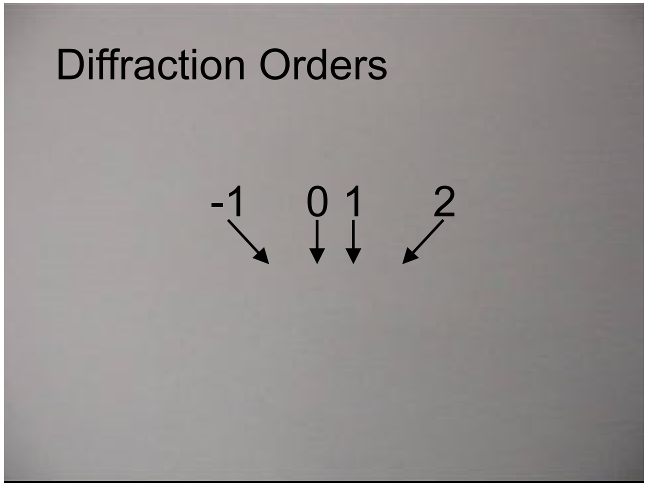
> Measurement: Relative power in diffraction orders

Order	-1	0	+1	+2
RF off	0%	100%	0%	0%
RF on	2%	8%	79%	8%

> Measured diffraction efficiency ≈80%

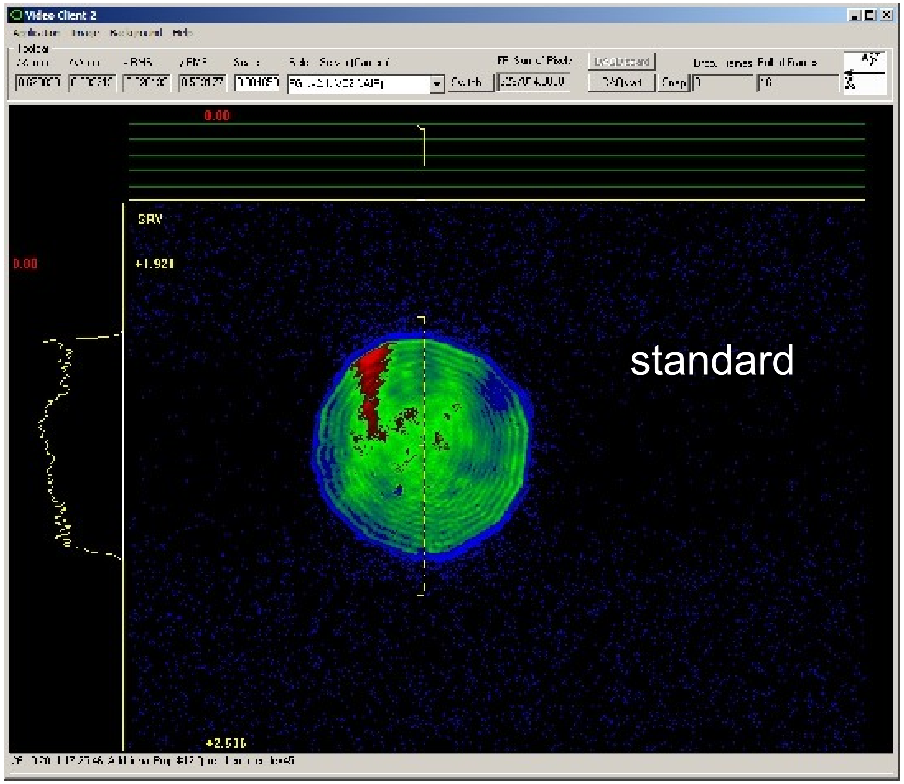
> With RF on almost all power in 1st order and next neighbor orders

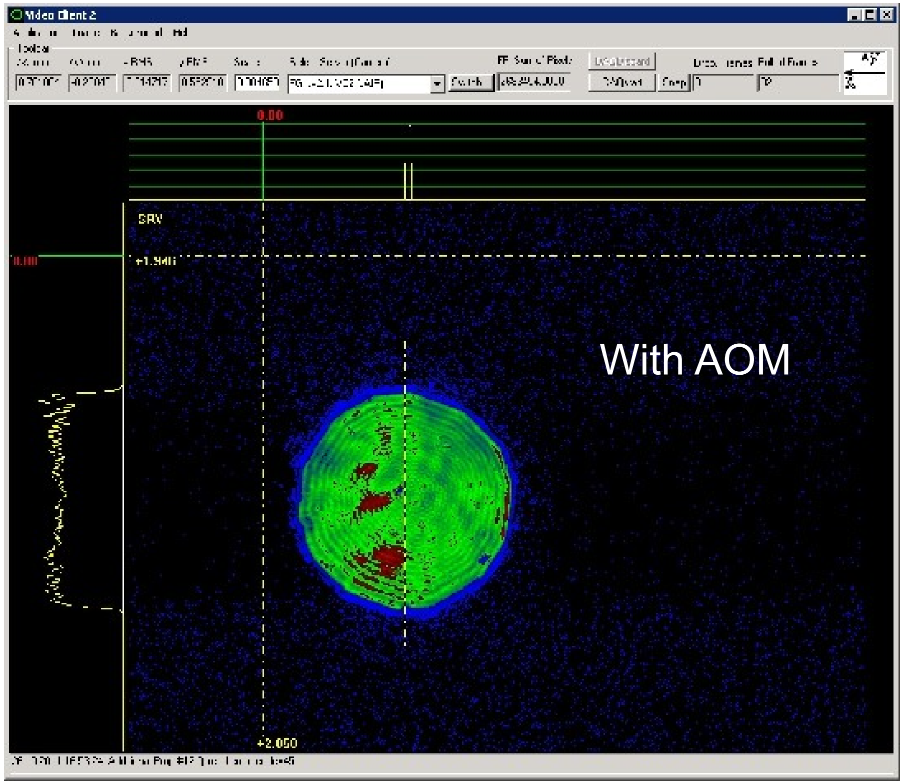
- SiO_2 has low optical losses in UV (<0.1% for AOM) should bring improvement to original problem



First Results (3)

> Measurement with VC2 (measured 26.10.2011A)





> No visible influence of AOM to lateral profile

Next steps

- Influence on temporal pulse profile (OSS)
- Total efficiency (energy meter)
- Determine extinction ratio (PMT, PCO camera)
- Energy/position-jitter over pulse train (PMT+PCO/VC2)
  - Synchronization of RF driver for acoustic wave to master oscillator – fix phase of acoustic wave when laser pulse arrives (available: 108MHz)
- Integration into PITZ μs timing system (GUI)
- Experiments with electron beam
  - Extinction ratio etc. as above
  - Bunch charge along pulse train
  - Emittance measurements?

Summary

- Photocathode laser: Influence of BBO conversion crystal warming on properties of electron bunches (Charge, arrival time etc.)
  - Seen at PITZ and FLASH
- Possible solution: UV Acousto-Optic Modulator (AOM) as pulse picker
- AOM was bought and is being tested at PITZ
- First results:
  - Fast enough to pick single pulses with high contrast ratio
  - Low loss / high diffraction efficiency
  - No visible influence on lateral profile
- Next: More experiments at PITZ, later FLASH(?)