TIMING AND SYNCHRONIZATION SYSTEM

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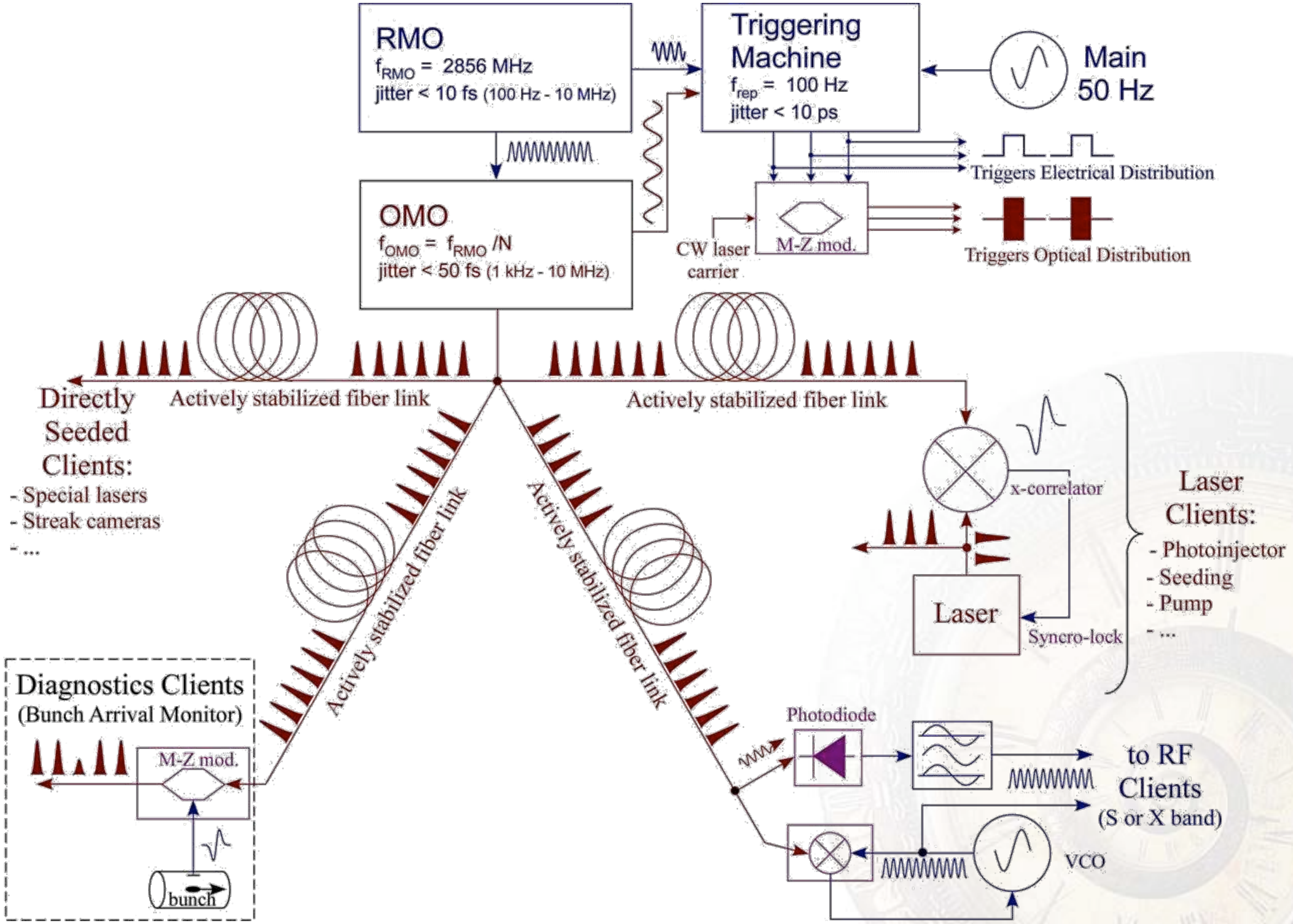
System overview



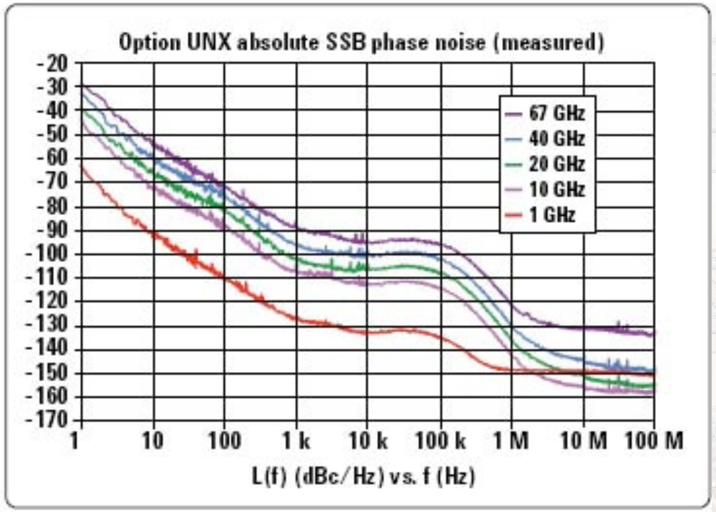
System specifications

Client	Jitter spec [fs]	Lock-in stability [fs]	Client Lock-in Bandwidth	Technology
Photoinjector Laser	200	240	5 kHz	SynchroLock (electro-opt or full opt.)
Laser Heater	150	130	5 kHz	SynchroLock (electro-opt or full opt.)
RF S-Band	150	130	1 MHz	Klystron Fast Phase Lock (LLRF)
RF X-Band	100	70	4 MHz	Klystron Fast Phase Lock (LLRF)
Seeding Lasers	100	70	5 kHz	SynchroLock (electro-opt or full opt.)
Streak Cameras	500	500	Full	Direct Seeding
Bunch Arrival Monitors	100	70	Full	Direct Seeding
Pump Lasers	100	70	5 kHz	SynchroLock (electro-opt or full opt.)
Triggers	10000	10000	---------	Electronic event generator and receivers

A 70fs jitter between reference oscillator and users due to propagation in fiber is assumed

Reference Master Oscillator

- Single reference oscillator
- Used to long term stabilize OMO frequency avoiding slow drifts
- No extreme performances needed
- Choice of commercial products (jitter <50fs from 10Hz to 10kHz)



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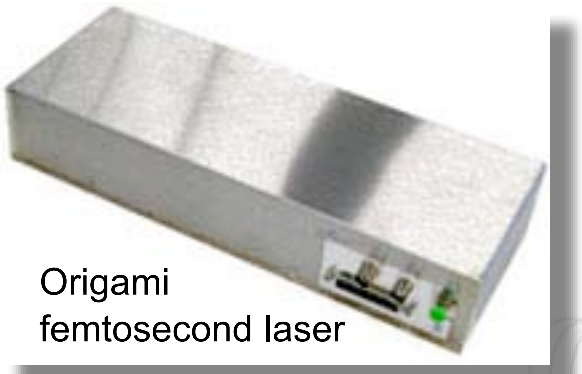
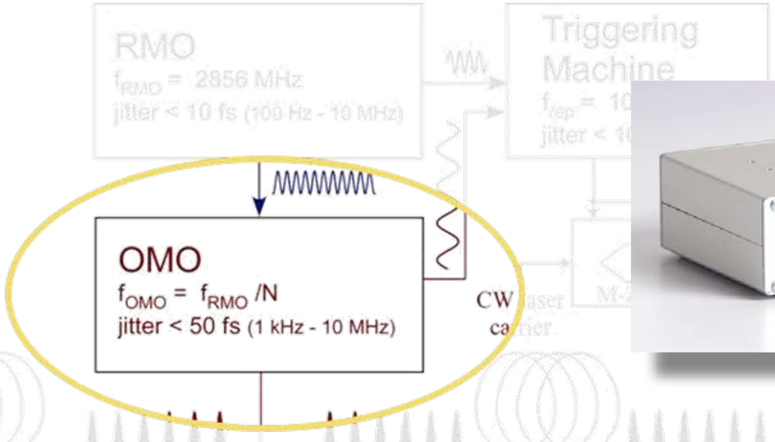
Optical Master Oscillator



Origami femtosecond laser

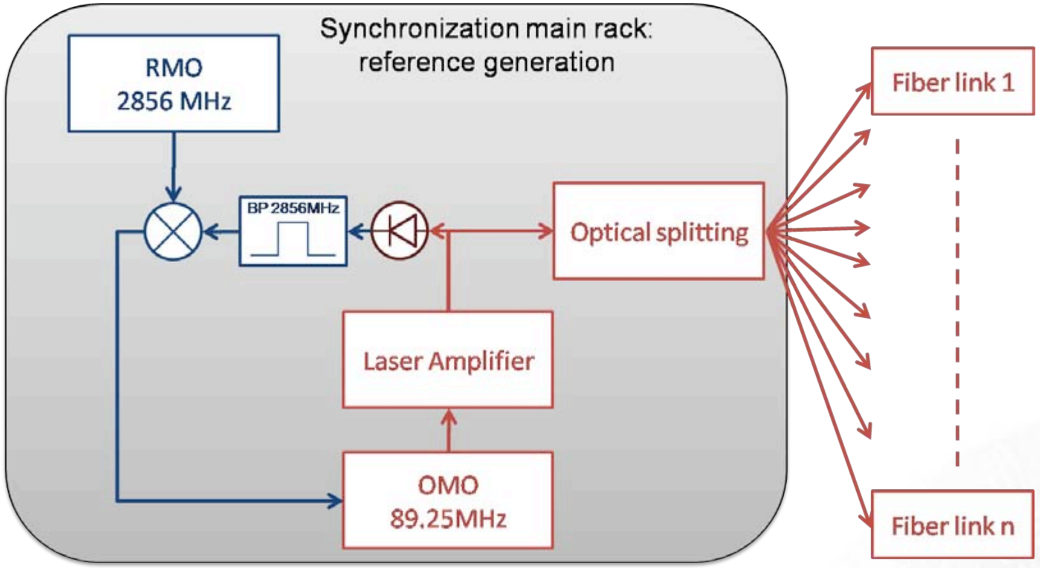


Synchronization unit

- A call for tenders for a OMO prototype has been won by OneFive Gmbh
- The laser oscillator is now under construction
- We are pl… …ork progress

Pulse width	*tpulse*	*< 200 fs*
Wavelength 1	*l1*	*1560 nm*
Wavelength 2	*l2*	*780 nm*
Pulse rep rate	*frep*	*89.250 MHz*
Pulse energy	*Epulse*	*> 2 nJ (~ 180 mW)*
Phase jitter	*trms*	*< 100 fs rms (SSB Df > 1 kHz)*
Amplitude jitter	*(D A/A)rms*	*< 0.05 % rms*
Synchrolock BW	*fcutoff*	*> 5 kHz*
Phase jitter relative to reference	*trel*	*< 10 fs rms (dc – 1 kHz)*

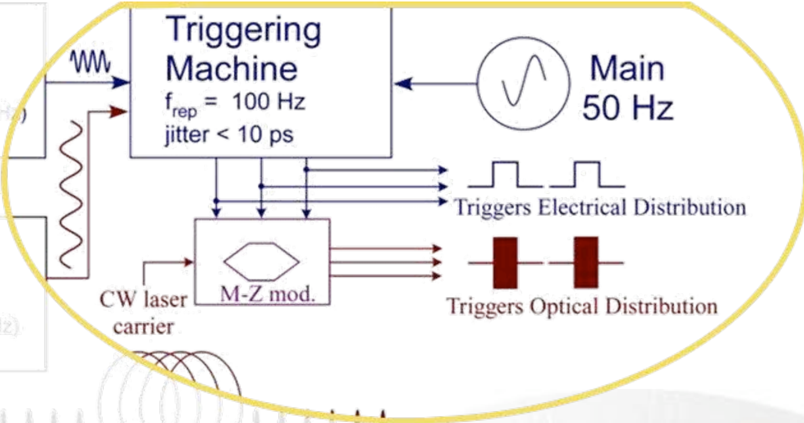
Reference signal generation

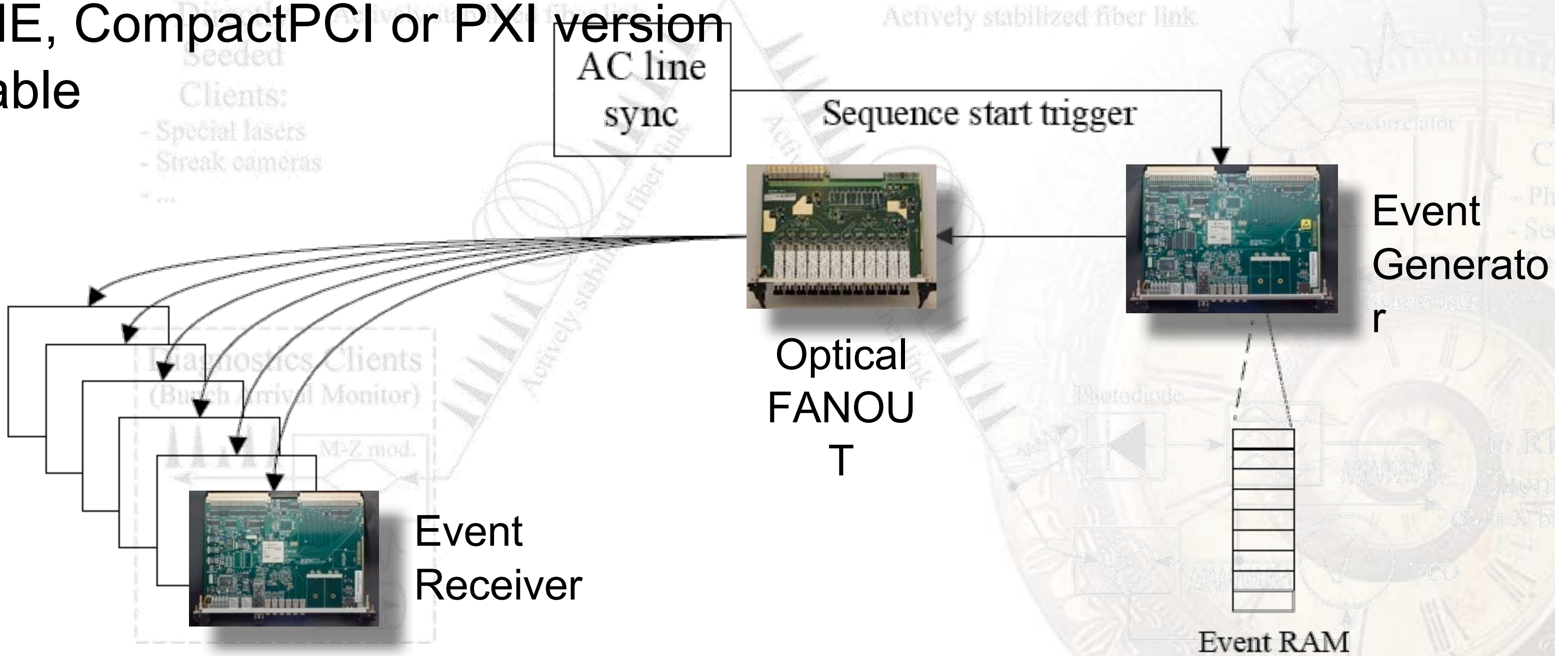


- Choice of a PLL operating directly at the 2856MHz main frequency
- In-fiber instead of in-air optical splitting
  - Avoid signal attenuation in fiber-air interfaces
  - Minimize mechanical noise added by optical components (vibrations, thermal elongation)
- We plan to keep the devices in a temperature controlled and mechanical stabilized environment

Timing generation and distribution

- ➢ Event generator and receiver structure
- ➢ System already developed, engineered and tested (LCLS, APS, Swiss Light Source, Diamond)
- ➢ Easy to integrate in the control system
- ➢ Status word information sent every shot
- ➢ VME, CompactPCI or PXI version available





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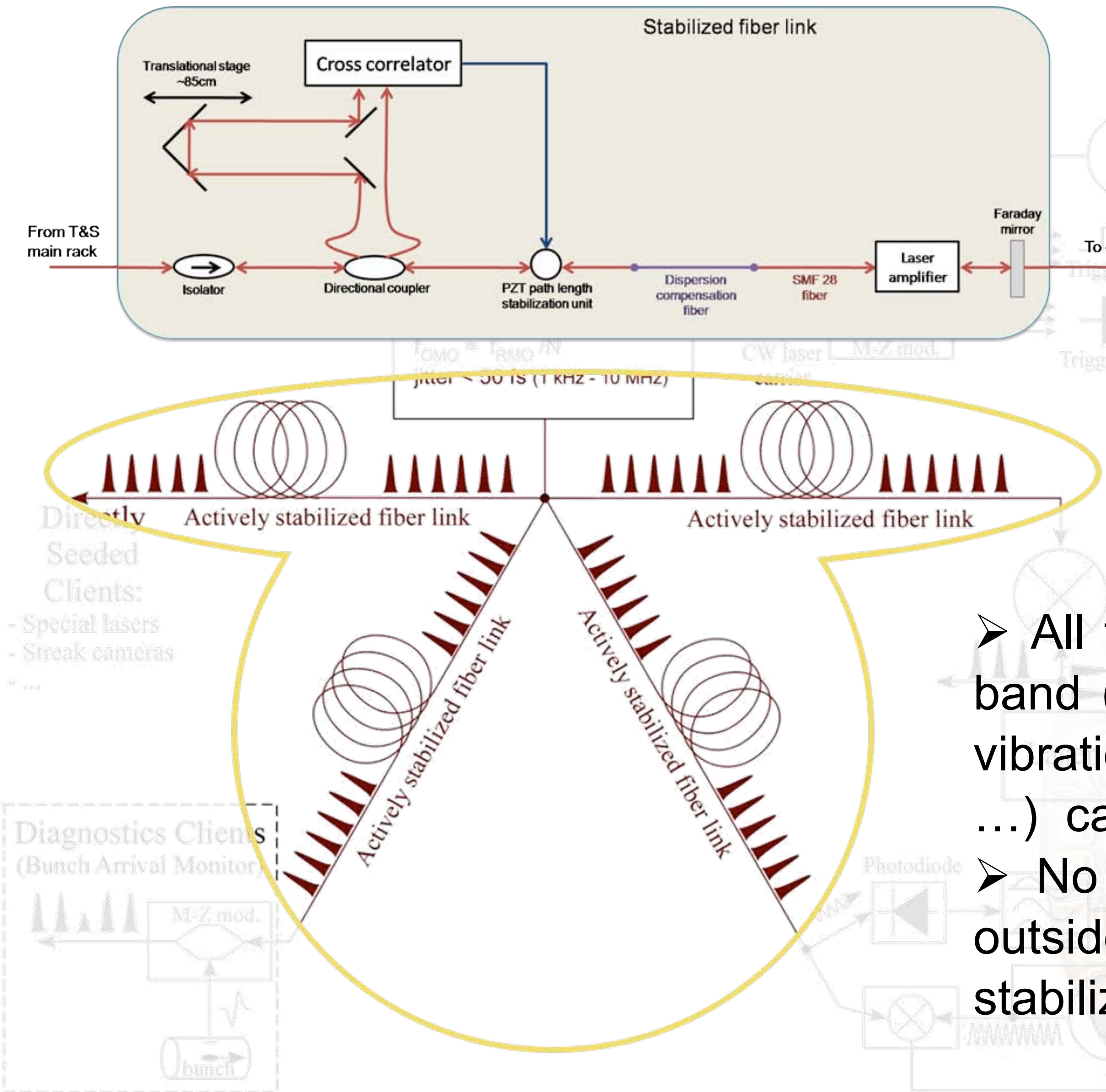
Reference signal distribution



At SPARX: $\boldsymbol{2DT \approx 2.5\ m}$

Loop BW limitation from physical delay f_{pd}:

$$2p\, f_{pd}\, 2DT = p/4$$

$$f_{pd} \approx 50\ kHz >> f_{PZT}$$

- ➢ All the noise in the dc÷10kHz band (thermal drifts, mechanical vibrations, mains disturbances, …) can be corrected.
- ➢ No major noise contributions outside the loop BW of the link stabilizers are expected.

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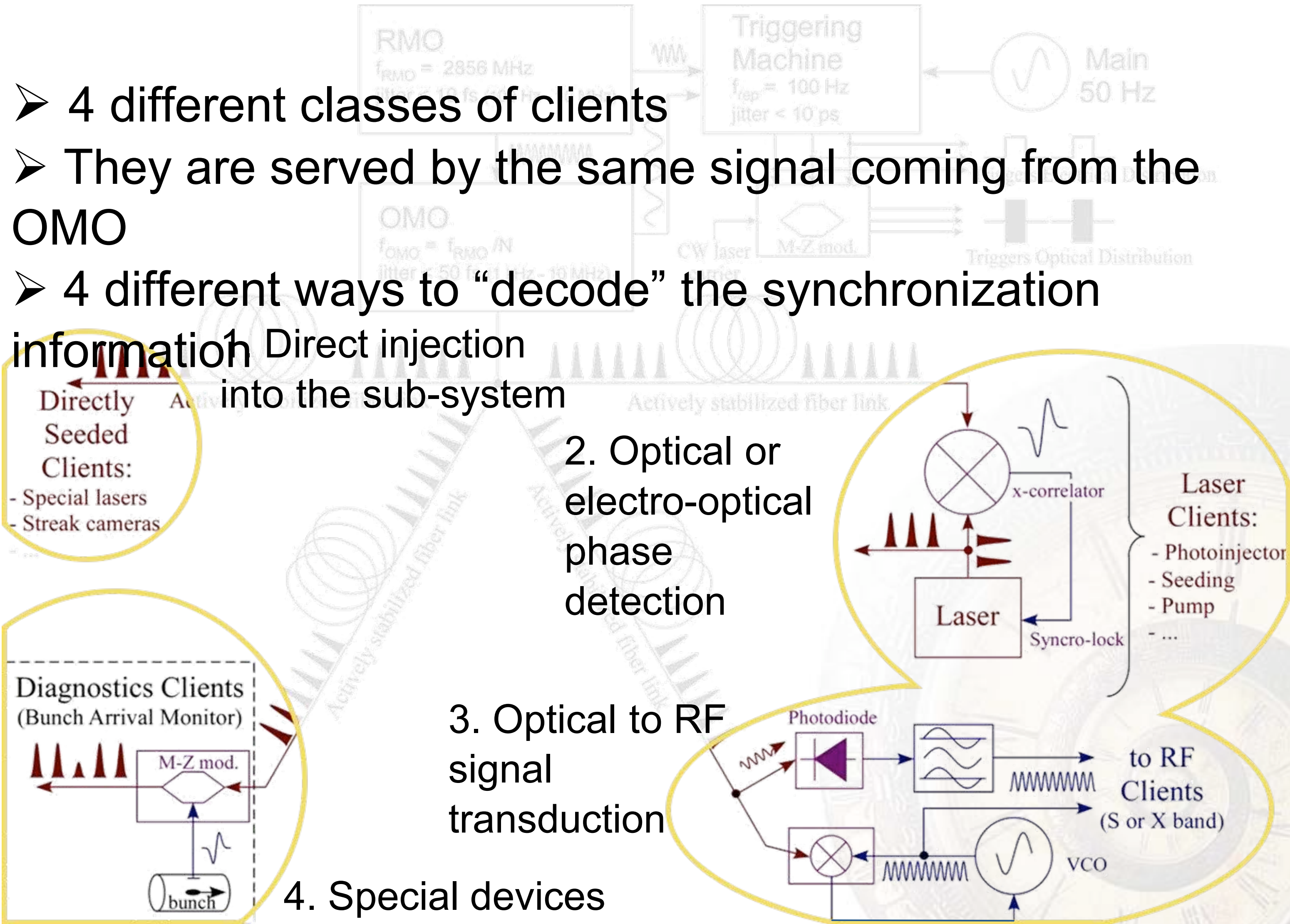
Clients synchronization

- 4 different classes of clients
- They are served by the same signal coming from the OMO
- 4 different ways to "decode" the synchronization information

1. Direct injection into the sub-system
2. Optical or electro-optical phase detection
3. Optical to RF signal transduction
4. Special devices



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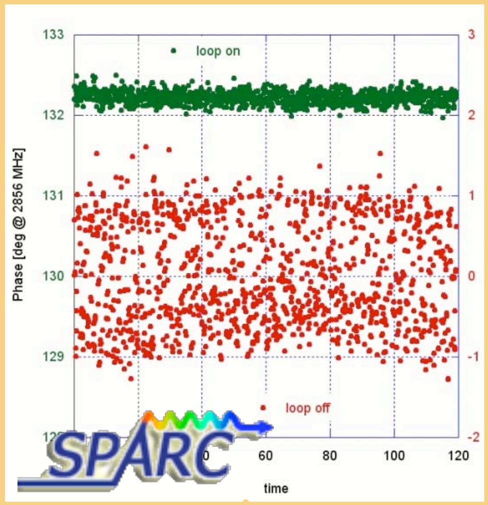
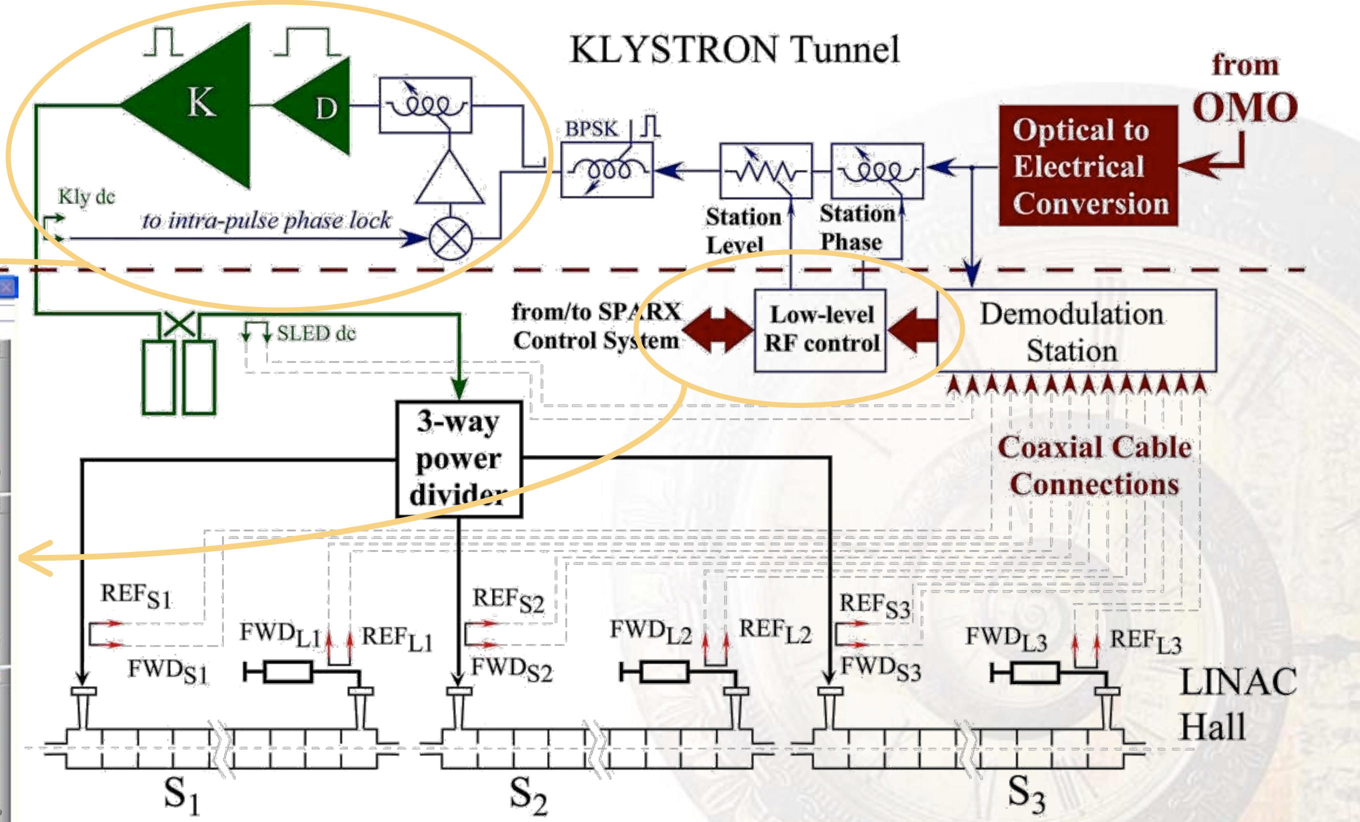
RF power station clients

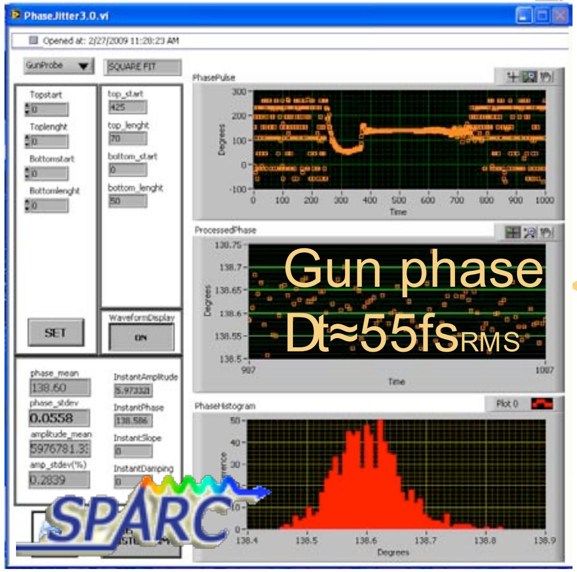


Dt≈77fs$_{RMS}$

Dt≈630fs$_{RMS}$

- Modular system: 1 klystron serves 3 sections
- 1 front-end PC to control each station
- 1 module tested @SPARC with success





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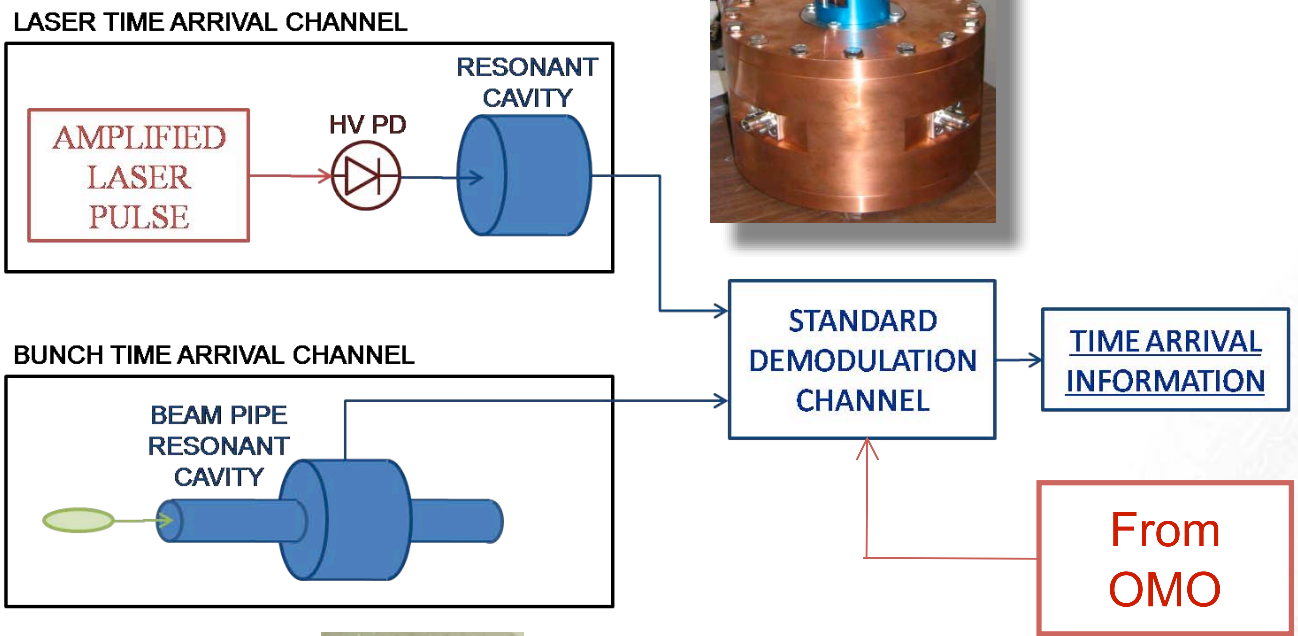
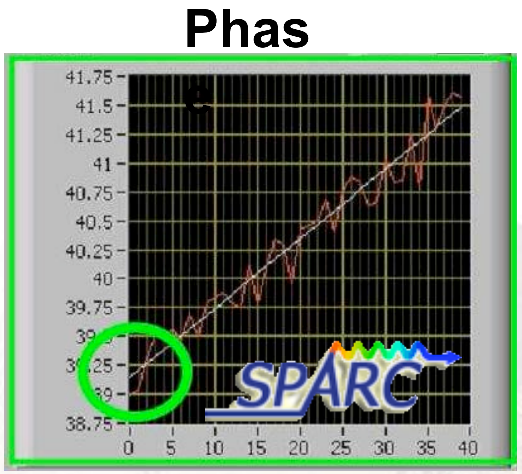
Diagnostics (1/2)

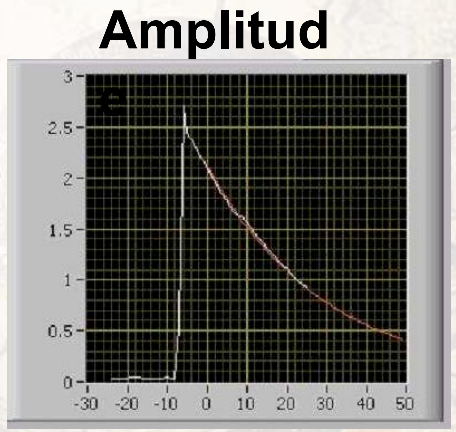
➢ 2142MHz cavity tuning frequency to avoid RF interference

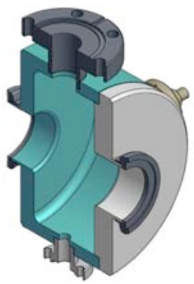
➢ ≈440 fs RMS jitter observed in normal operation

➢ couldn't measure the detector resolution yet





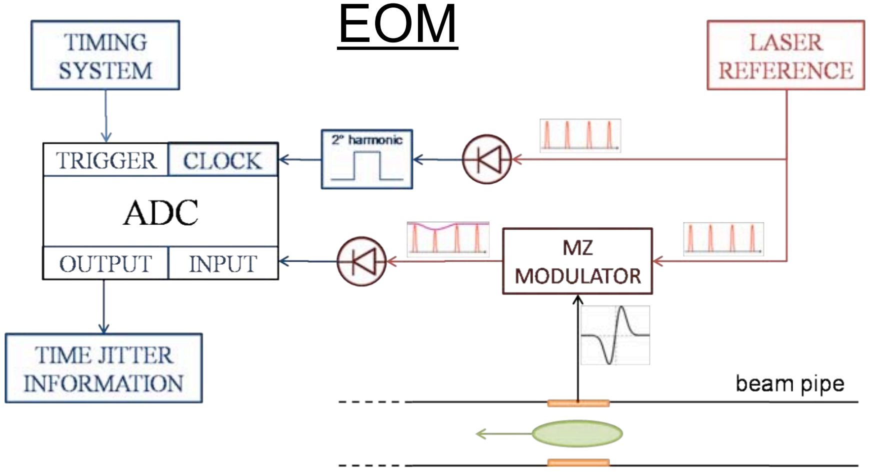




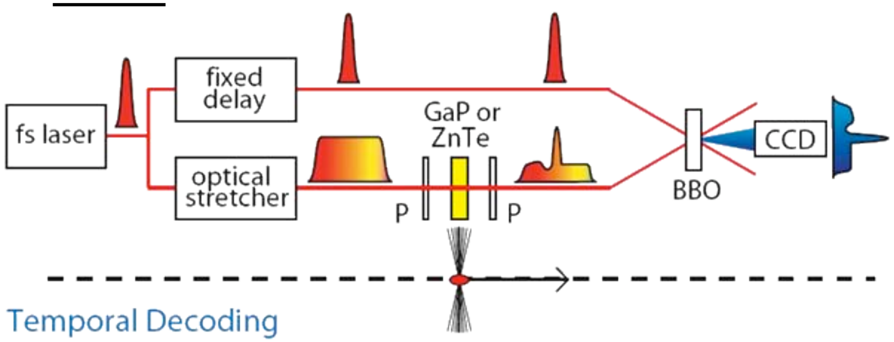
➢ in-pipe cavity ready to be installed and tested @SPARC

Diagnostics (2/2)

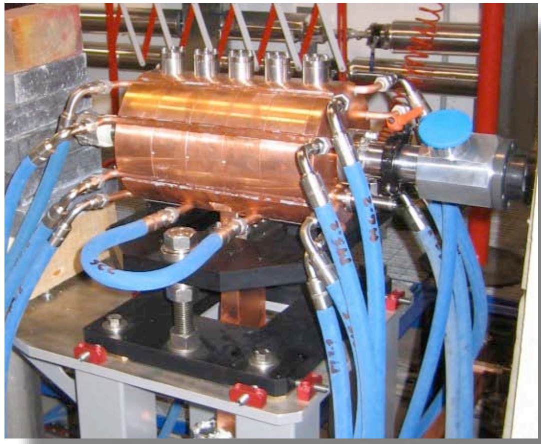
EOM

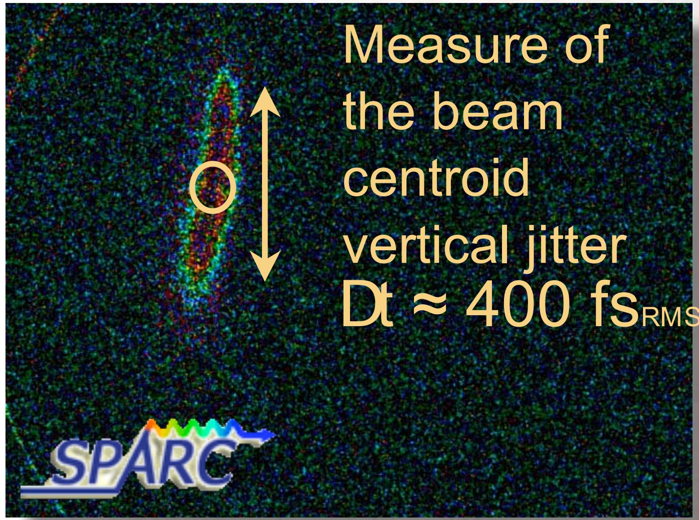


EOS



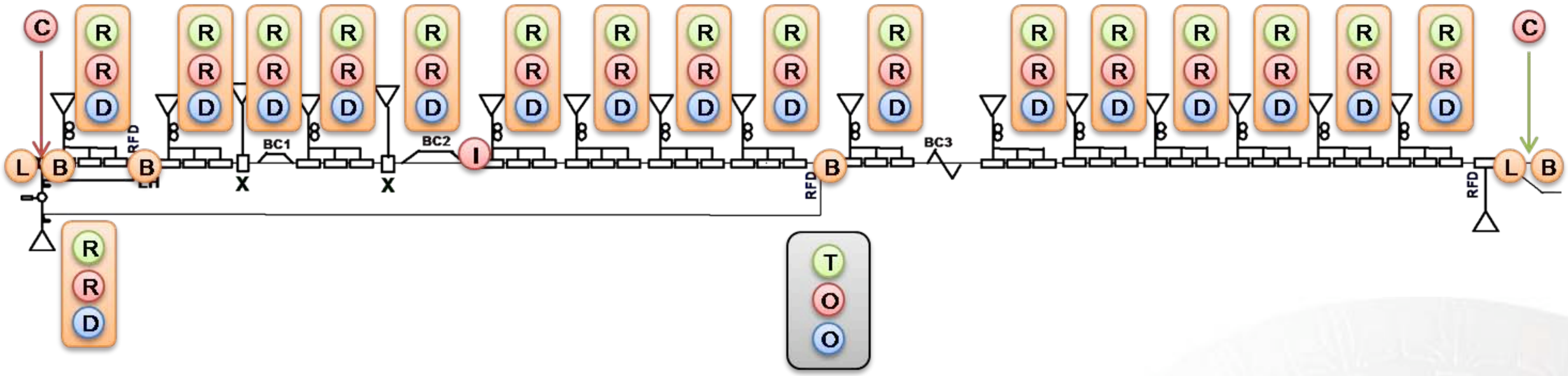
RF deflector





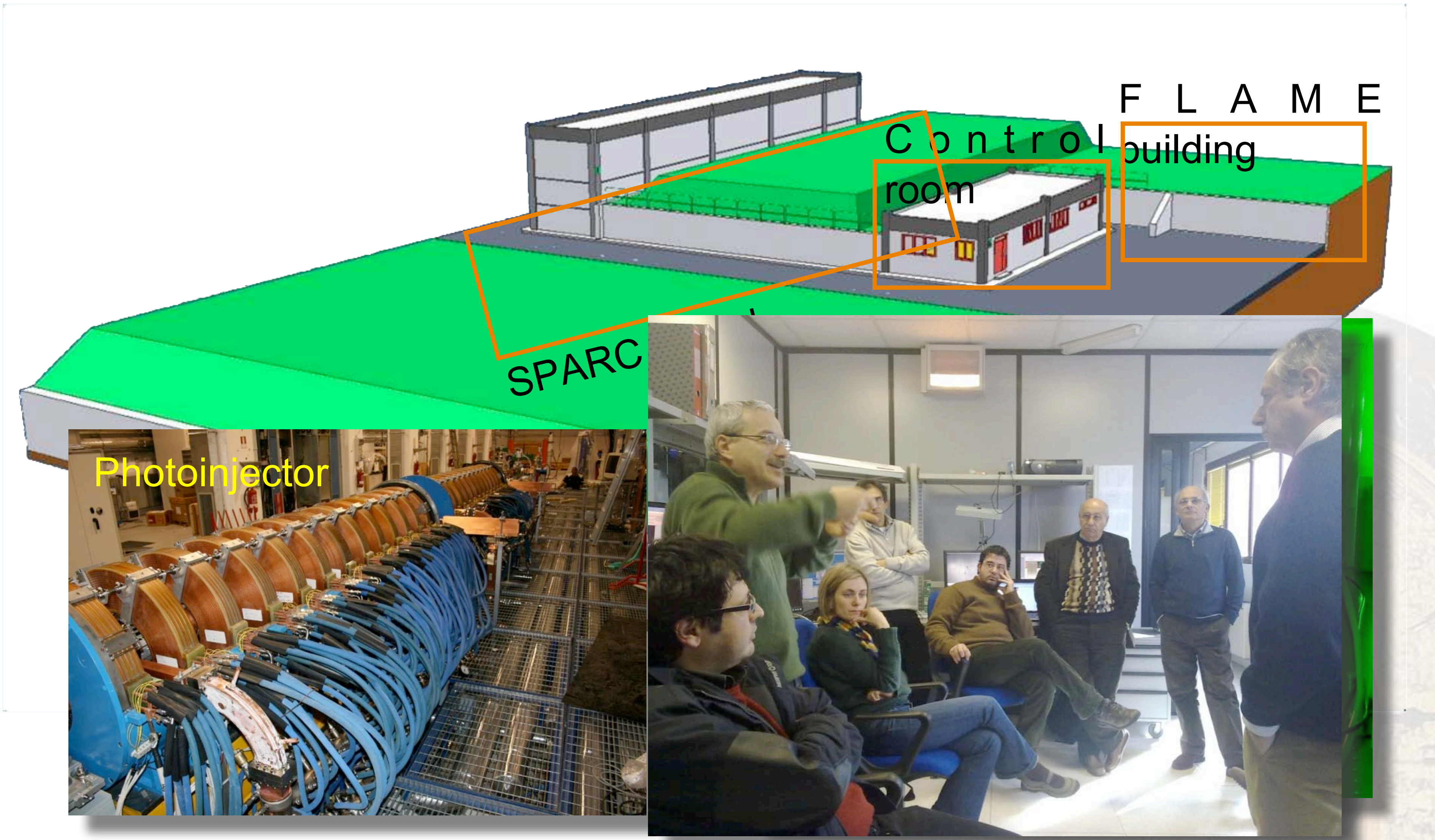
- SPARC implementation in collaboration with CNR Pisa
- FERMI test bench @SPARC in collaboration with ST

System layout



- (O) Optical master oscillator and optical fiber signal transmitter
- (R) Optical fiber reference signal receiver for transduction
- (O) Electric master oscillator
- (D) Demodulation board for phase information extraction
- (T) Trigger, event and time stamp generator and transmitter
- (R) Trigger, event and time stamp signal receiver
- (C) Optical cross-correlation
- (L) Laser arrival monitor
- (B) Bunch arrival monitor
- → Photo-injector laser
- → Seeding lasers
- (I) IR photo-detector
- T&S main rack
- T&S local rack

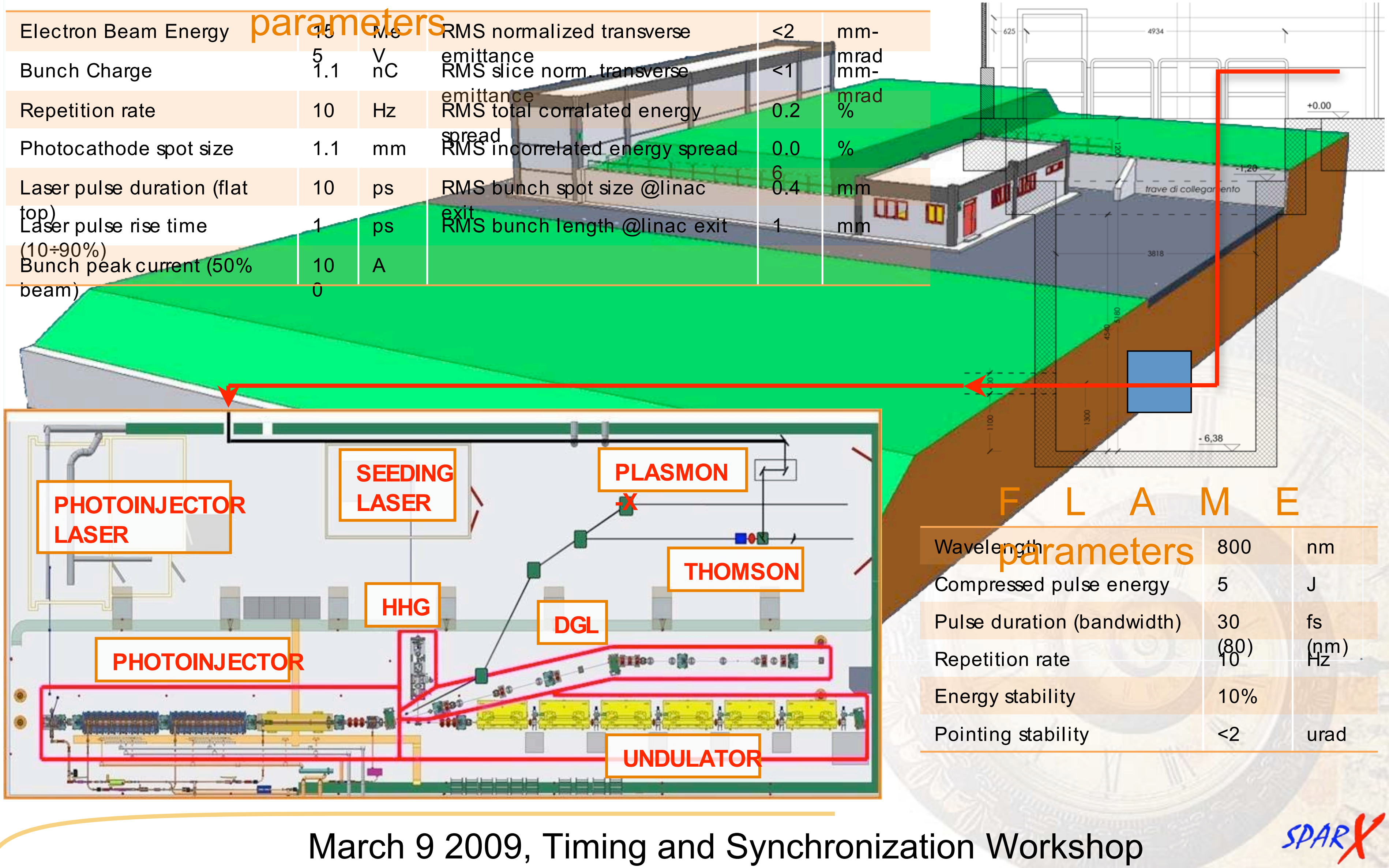
Bringing SPARC to LIFE (1/3)



Bringing SPARC to LIFE (2/3)

SPARC nominal parameters

Electron Beam Energy	155	MeV	RMS normalized transverse emittance	<2	mm-mrad
Bunch Charge	1.1	nC	RMS slice norm. transverse emittance	<1	mm-mrad
Repetition rate	10	Hz	RMS total corralated energy spread	0.2	%
Photocathode spot size	1.1	mm	RMS incorrelated energy spread	0.06	%
Laser pulse duration (flat top)	10	ps	RMS bunch spot size @linac exit	0.4	mm
Laser pulse rise time (10÷90%)	1	ps	RMS bunch length @linac exit	1	mm
Bunch peak current (50% beam)	100	A			



FLAME parameters

Wavelength	800	nm
Compressed pulse energy	5	J
Pulse duration (bandwidth)	30 (80)	fs (nm)
Repetition rate	10	Hz
Energy stability	10%	
Pointing stability	<2	urad

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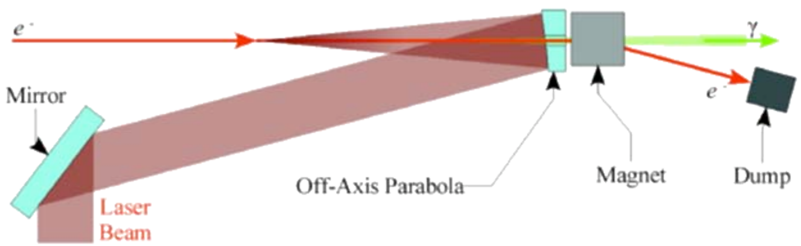
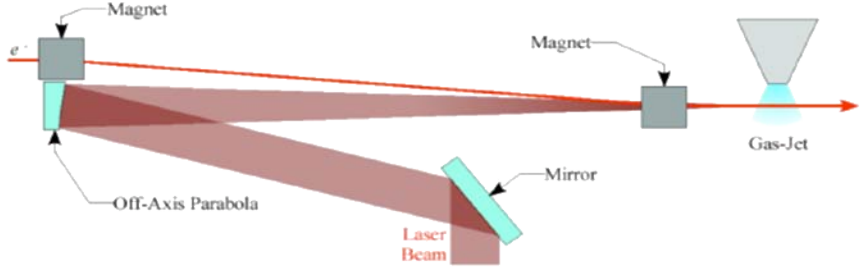
Bringing SPARC to LIFE (3/3)



Thomson scattering experiment: requires physical overlapping of SPARC and FLAME beams within the depth of focus of the laser focusing optics.

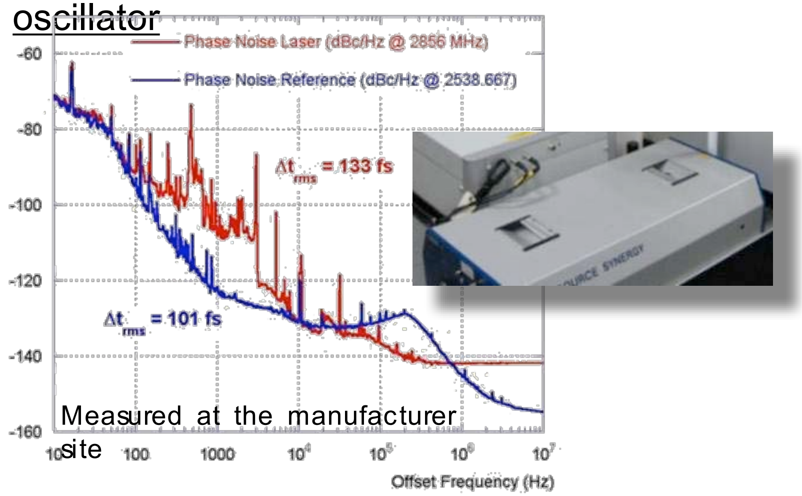
Stability required <1 ps (PLASMON–X, MAMBO)



Plasma acceleration experiment: SPARC and Flame pulses injected in a gas jet, requires synchronization at the level of the period of the plasma wave.

Stability required <100 fs (PLASMON–X)

Phase spectrum of the Flame laser oscillator

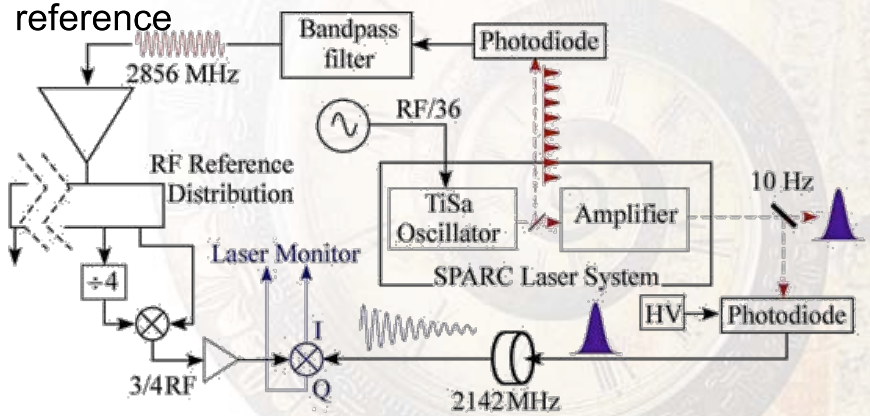


Measured at the manufacturer site

Absolute jitter: 133 fs Relative jitter: <90 fs

SPARC synchronization upgrades

- laser PLLs upgrade (harmonic phase detection @2856MHz)
- use of the photo cathode laser oscillator as reference



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Conclusion

- Part of the client side of the SPARX synchronization system tested at SPARC
- Cavity resonant diagnostics tested at SPARC
- Resonant BAM ready to be installed at SPARC

- OMO to be delivered in May
- Synchronization lab is in preparation
- SPARC upgrade towards LIFE is under way
- SPARX synchronization system to be built and tested
- Electro-optical PLLs to be built and tested

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