ICFA FLS workshop Desy 15-19 May 2006

Timing Concepts for the FERMI@ELETTRA facility

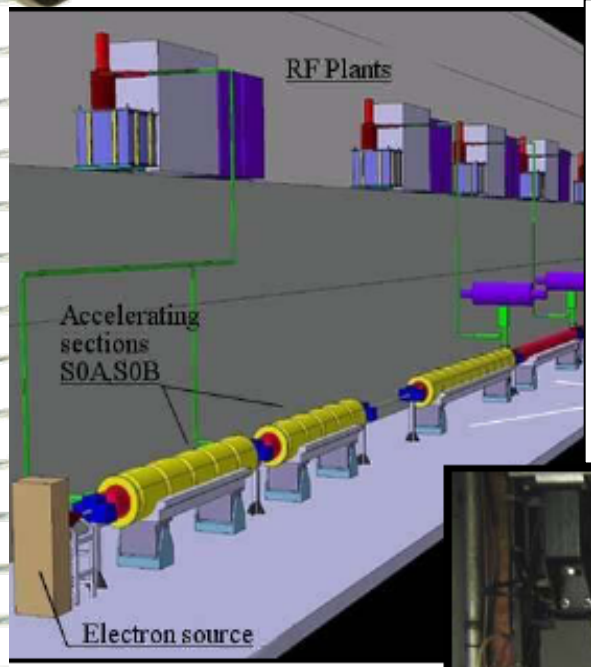
- FERMI@ELETTRA: some general notes
- Framework of the Timing system development
- FERMI timing system proposal
- On going activities at ELETTRA

Mario Ferianis - Sincrotrone Trieste, Italy

FERMI@ELETTRA: some general notes

- FERMI, a 4th G. L. Source based on the seeded FEL concept, has been designed to exploit as much as possible the existing 1GeV LINAC, used since 1993 as injector to the ELETTRA Storage Ring
- Two development steps are foreseen for FERMI:
  - FEL1, providing coherent photons in the **100 to 40nm** range
  - FEl2, providing coherent photons in the **40 to 10nm** range
- Time schedule is very tight:
  - FEL1 radiation is foreseen for 2nd half 2008
  - FEL2 in 2009-2010
- Main actions taken to reach these objectives:
  - Getting funded: done!
  - Increase internal manpower: running.
  - Activate external collaborations: running.

ELETTRA LINAC upgrade



Uses the upgraded Normal Conducting S-band (2998 GHz) ELETTRA linac

Fixed e-beam energy, 50 Hz operation, 1 electron bunch/pulse

Spectral range covered by two undulator lines - Seeded Harmonic Generation

FEL 1: 100 – ~40 nm (12–30eV) single stage

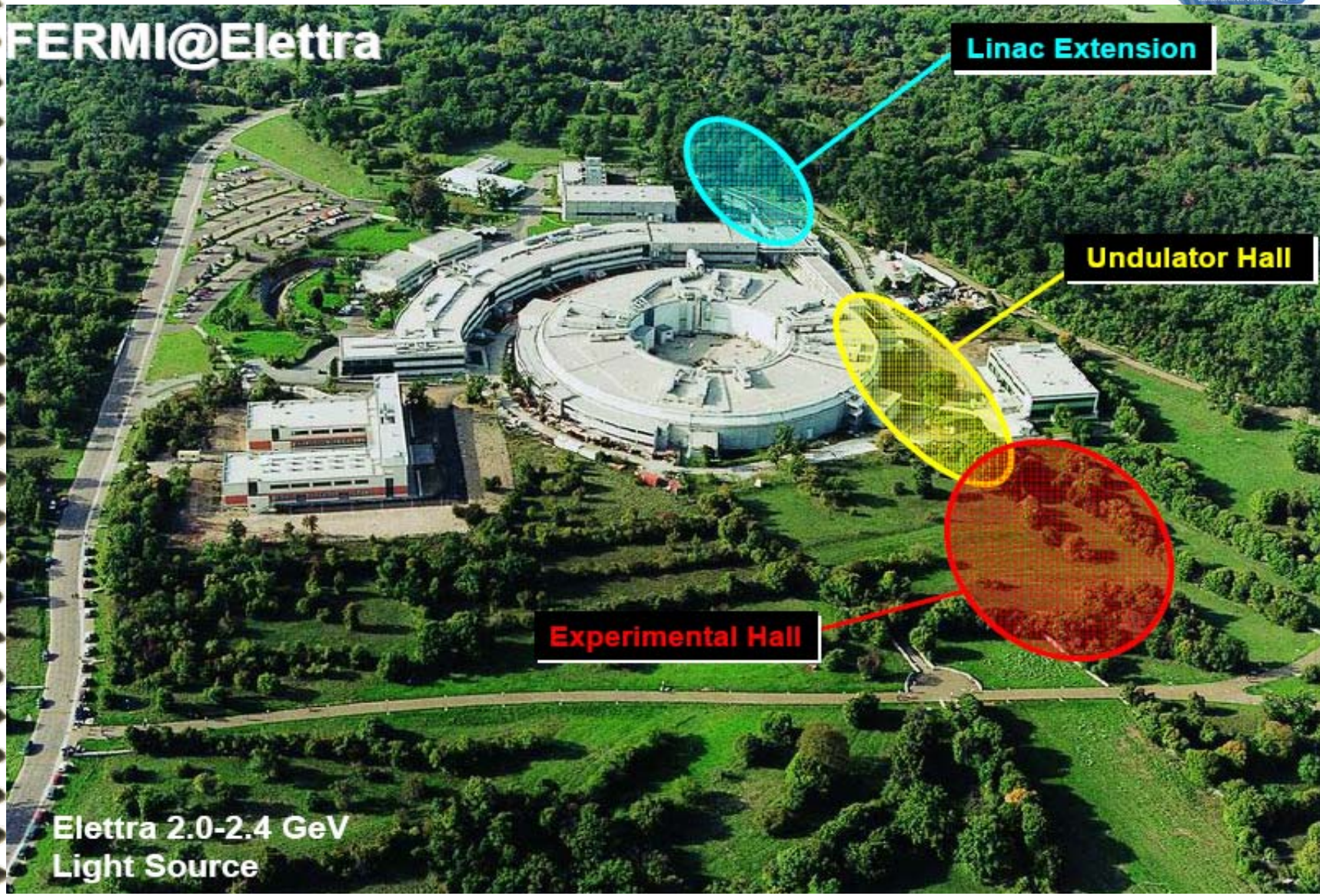
FEL 2: ~40 – 10 nm (30–124eV) two stages

Each FEL will feed two or more beamlines

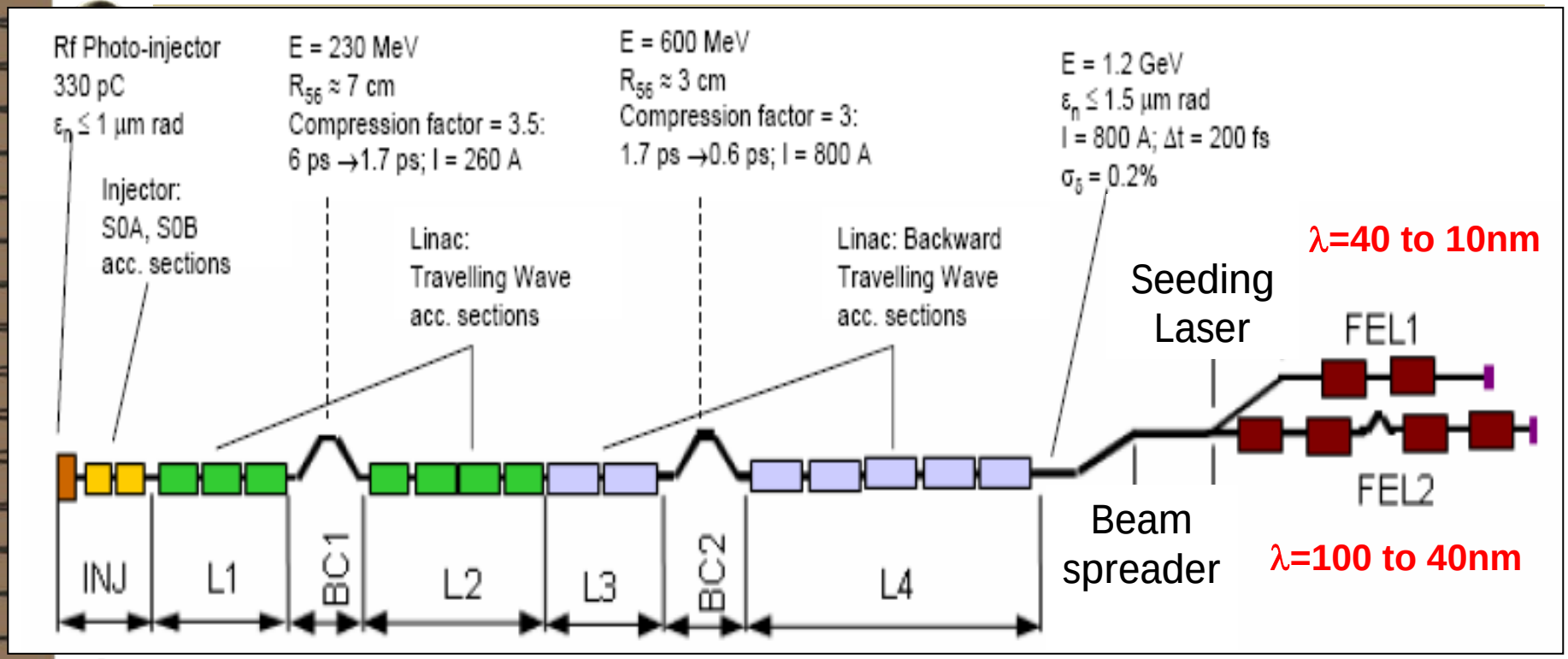
Gap tuning, Flexible polarization, Apple Type Undulators (radiators)

Variable photon pulse lengths (narrow bandwidth operation) 0.05 to ~1.0 ps

Civil engineering tasks



FERMI layout (in progress)



Timing and Synchronization issues for a seeded FEL

- Timing has to provide an ultra-stable (<10fs$_{RMS}$ timing jitter) reference signal to the accelerator, FEL and experimental area
- Synchronization has to keep the electron bunch stable w.r.t. the reference:
  - by measuring the “bunch phase” / energy fluctuations
  - by applying **correction loops** to the accelerator
- In 4GLS, timing and synchronization are key sub-systems:
  - **sub-ps bunch length**, achievable in single pass accelerator
  - extensive adoption of **ps** and **fs lasers** embedded in the radiation production process (photocathode, seed laser) and for time resolved experiments
  - **for seeded FELs** the required synchronization (electron bunch to seed laser) is <100fs level

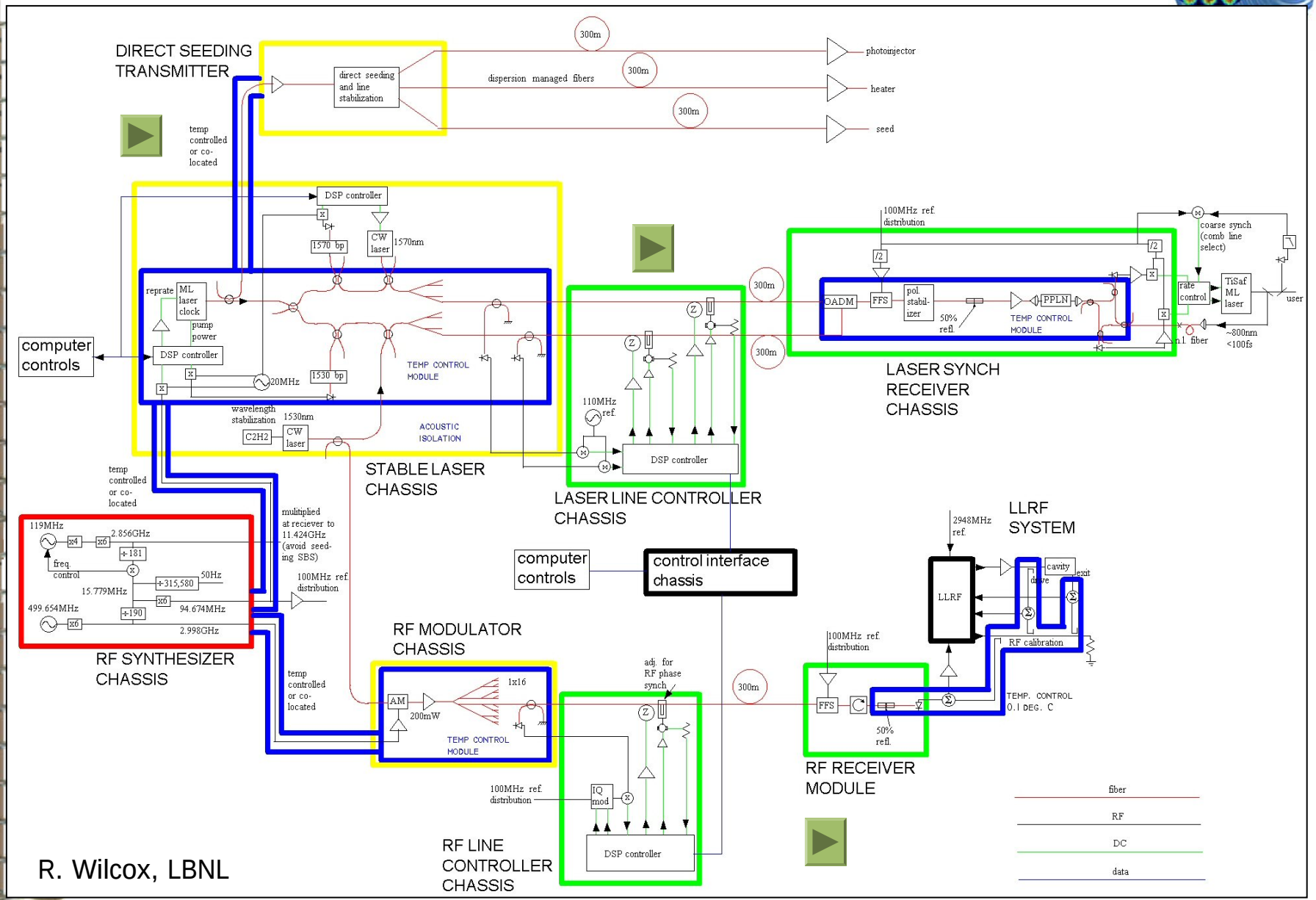
Framework for Timing & Synchronization development

- A *Technical Optimization Study* (TOS) team has been created last year that includes colleagues from *LBNL*, *MIT* and *SLAC*
- TOS output will appear as a *Conceptual Design Report* (CDR), due by the end of June ’06
- Specifically on *Timing & Synchronization* are active:
  - the **FERMI TOS** team (LBNL, MIT and ELETTRA)
  - the **EUROFEL** FP6-Design Study (2005-2007), workgroup DS3
- within EUROFEL, collaborations have been activated with:
  - **CNIT** an Italian University Consortium active in GB Optical Communications (fiber lasers) and based in Pisa
  - recently, **DESY** to participate in the “bunch phase” monitor project
  - University of Ljubljana (SLO): starting up

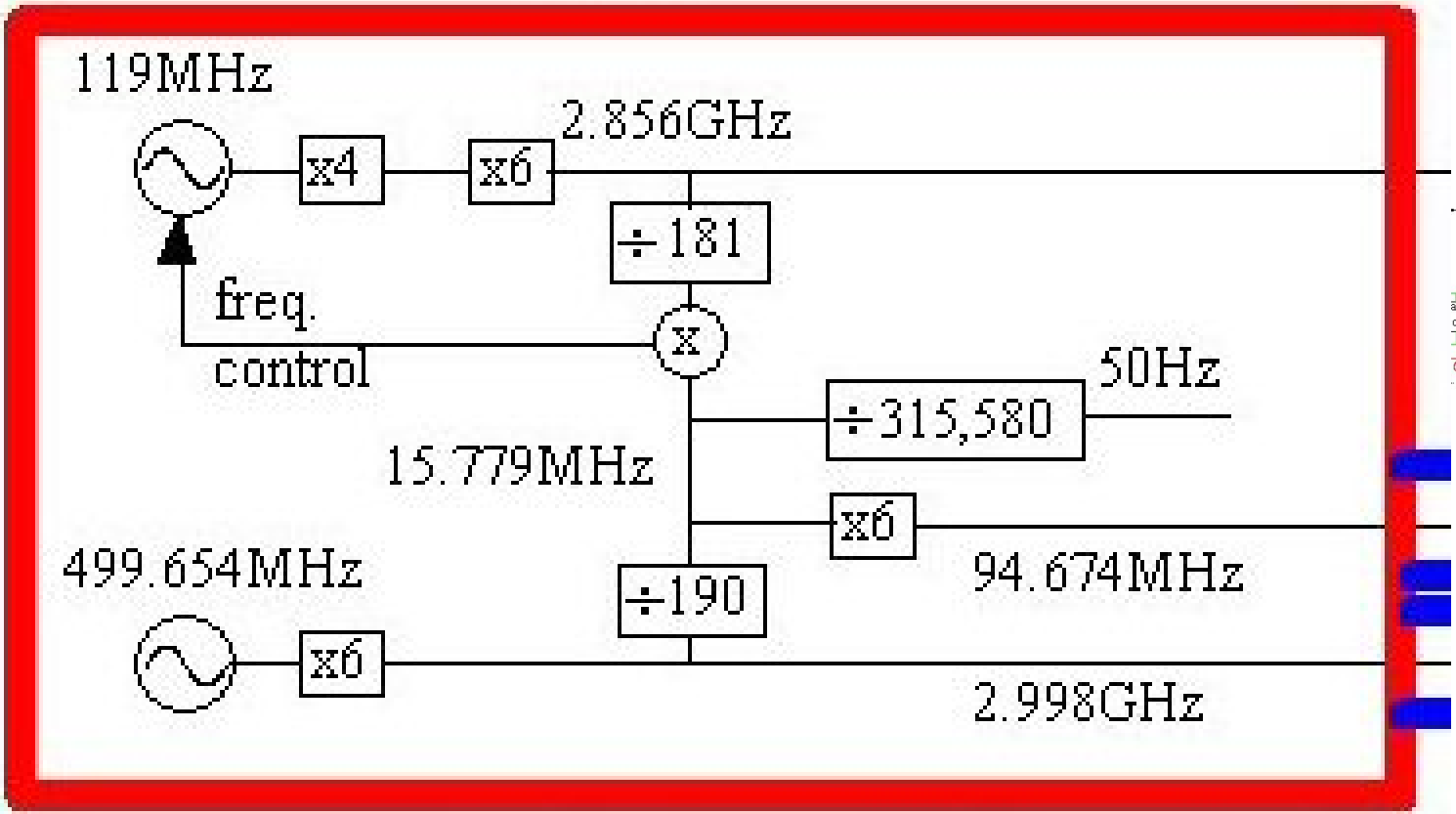
FERMI TOS output on Timing & Synchronization

- **LBNL team**:
  - J. Byrd, J. Staples, R. Wilcox, A. Ratti and L. Doolittle
- **MIT team**:
  - F. X. Kaertner, F.O. Idlay, J. Kim et al.
- **DESY team** (developing a “MIT-like” timing system for X-FEL):
  - H. Schlarb, A. Winter, F. Ludwig
- The final proposal for the FERMI timing and synchronization system includes both the:
  - **MIT timing system** also referred to as “time domain approach”
  - **LBNL timing system** known as “frequency domain approach”
- This solution enables the sharing of the R&D effort leading to an open exploitation of achieved results, in the frame of an improved synergy between laboratories

TOS timing block diagram

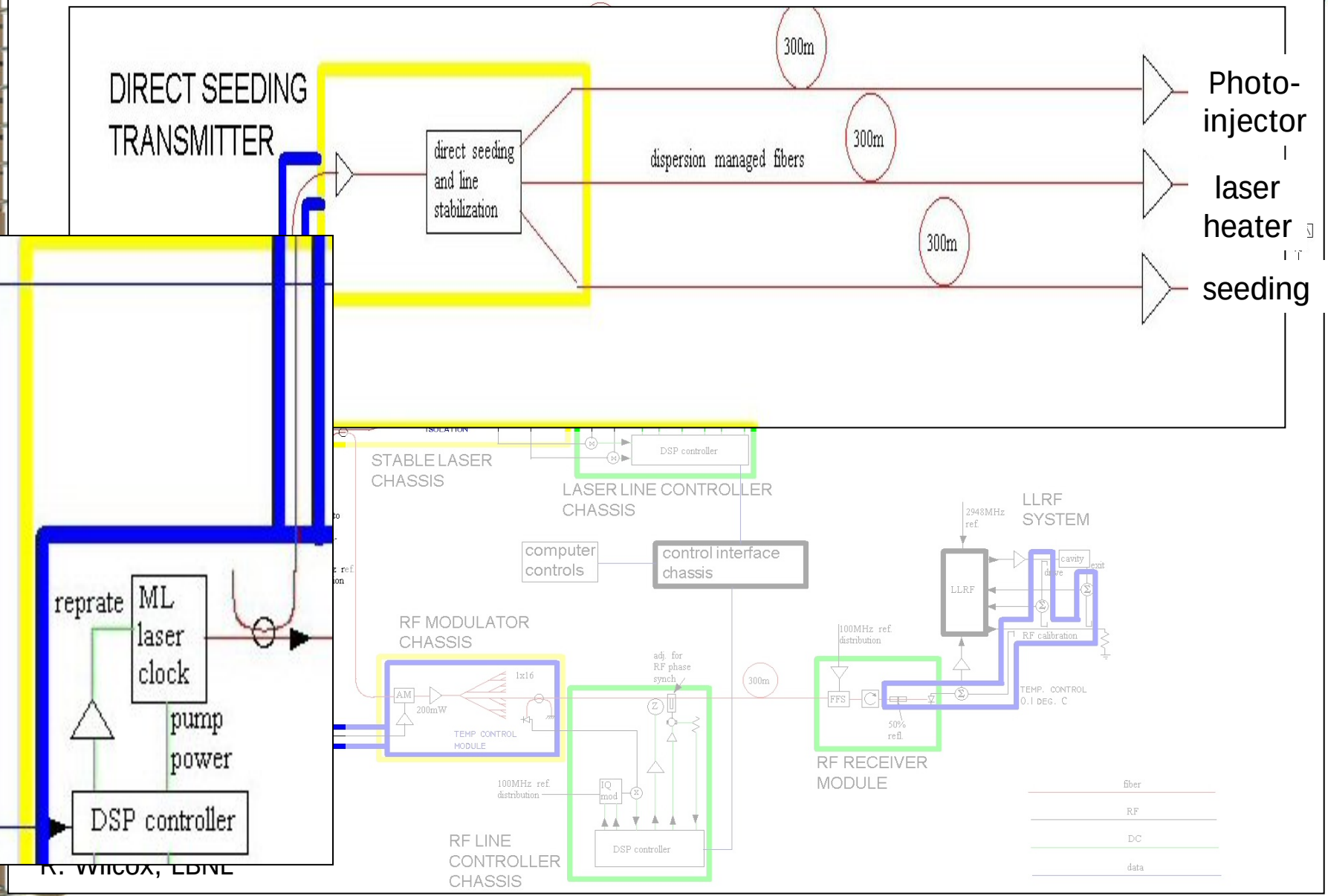


TOS timing block diagram



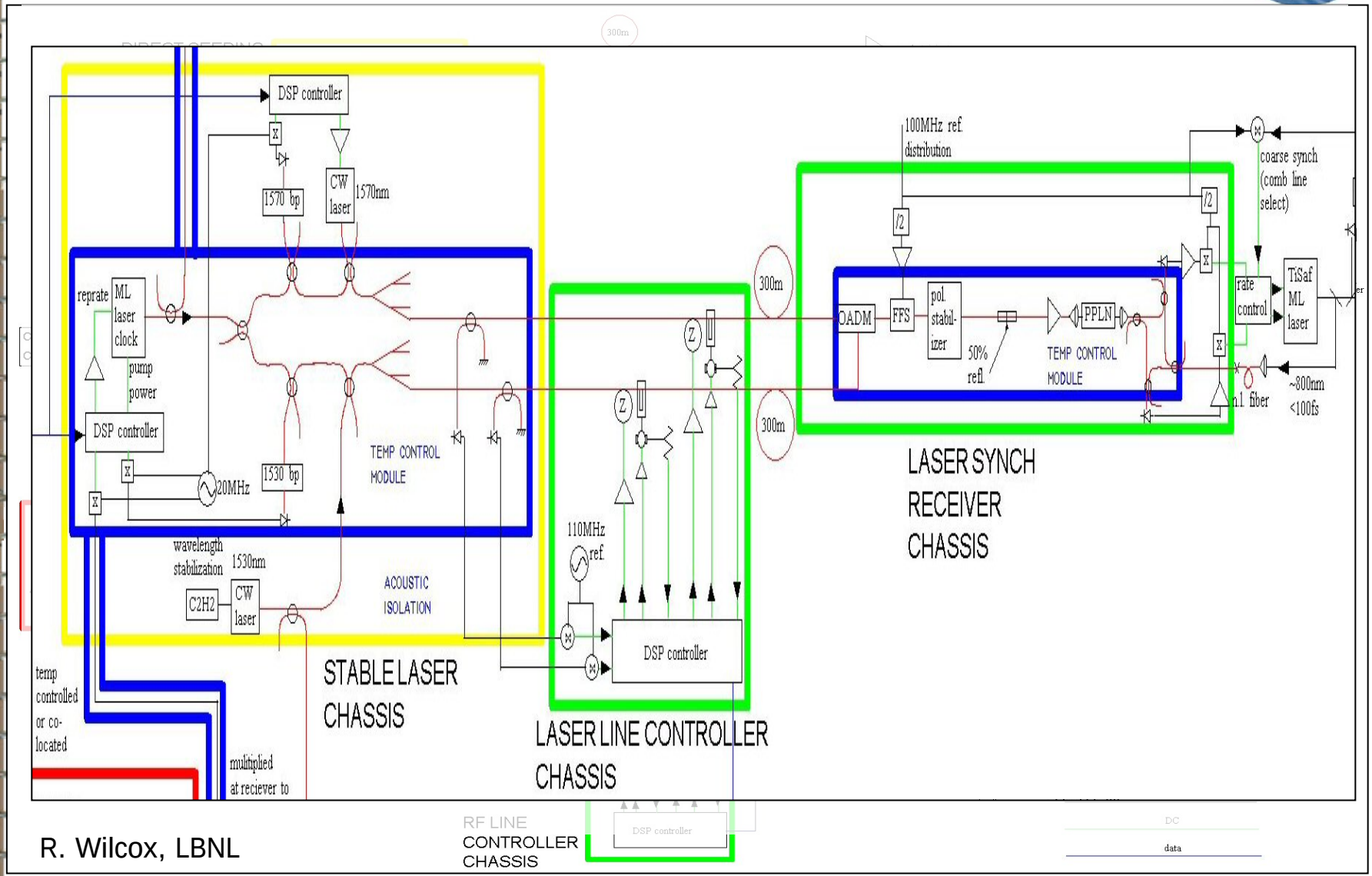
RF SYNTHESIZER CHASSIS

TOS timing block diagram



R. Wilcox, LBNL

TOS timing block diagram



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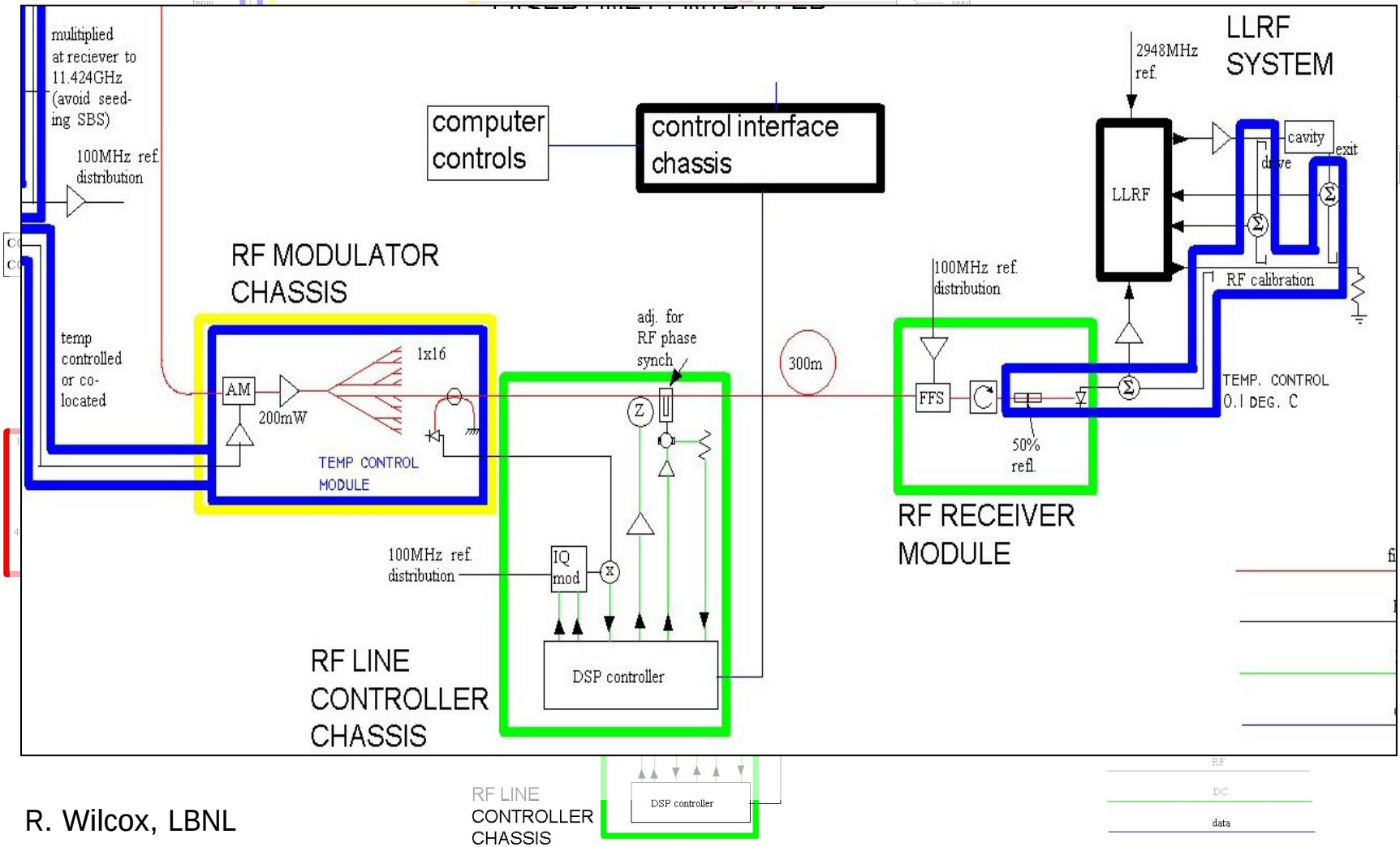
TOS timing block diagram



R. Wilcox, LBNL

LBNL timing vs. MIT timing

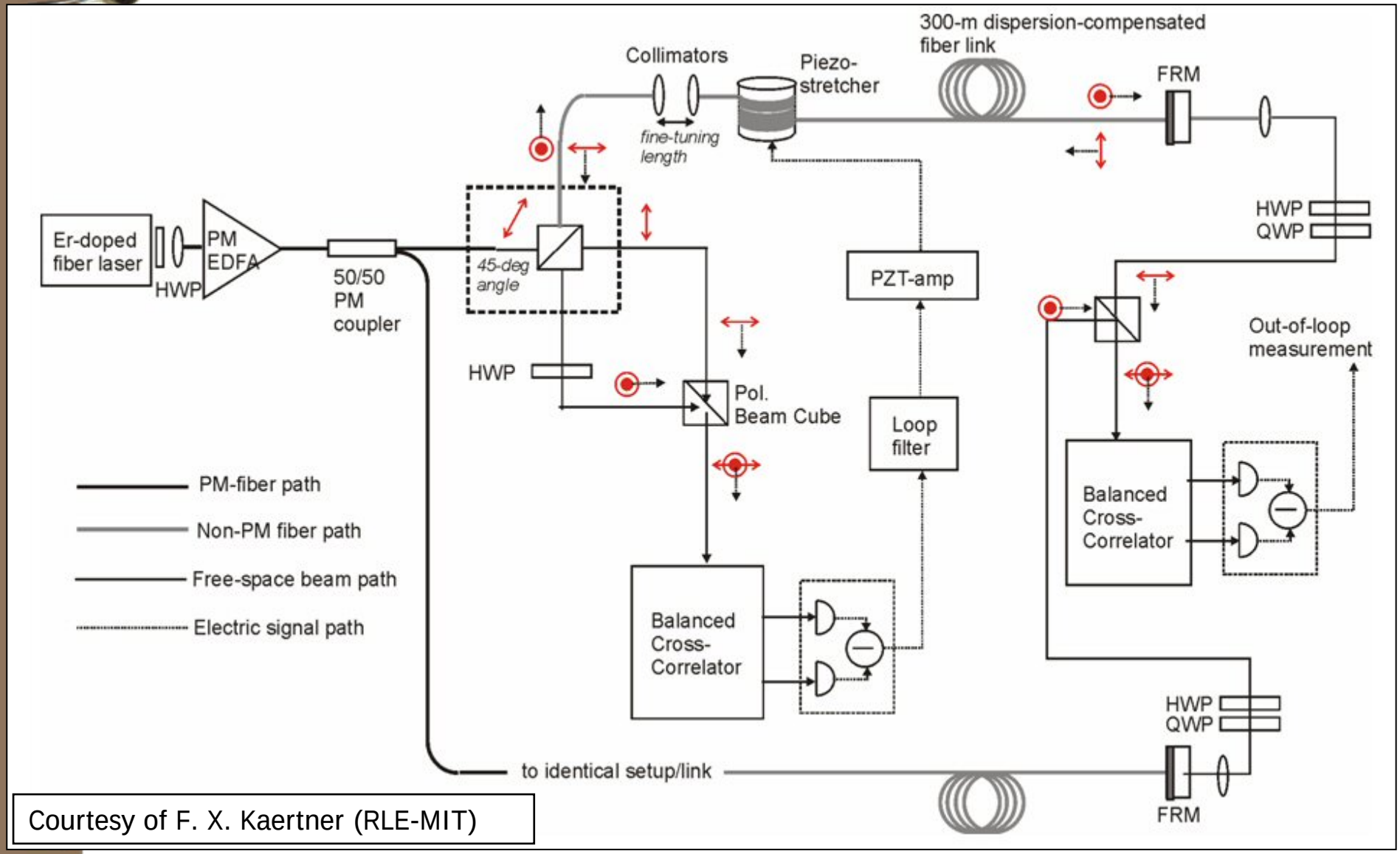
MIT timing, time domain		LBNL, frequency domain	
PRO	**CON**	**PRO**	**CON**
Group delay compensation	Power limit <30mW	High temporal resolution	Needs group delay compensation
Transmission of fundamental & harmonics	Output pulse shape limited	Direct optical synchronizati on at 5THz carrier	Needs mode locked receiver laser
Possible direct seeding of remote optical amplifier	GVD, SPM, SRS	No non-linear effects <100mW	Brillouin scattering >100mW

Reference: FERMI Technical Review Panel meeting, Nov 2005

TOS follow-ups …

- MIT will implement a test bed with two stabilized fiber optic (FO) distribution links fed with a dedicated Optical Master Oscillator (OMO)
- The repetition rate is set to $f_{REP} = f_{RF} / 5 = 599.586MHz$
- Out-of-loop phase noise measurement target are:
  - $<50fs_{RMS}$ timing jitter; 1st step, to operate the Front-end
  - $<10fs_{RMS}$ timing jitter; 2nd step, suitable for operation with seeding, fresh bunch technique
- After completion of the 1st step, the test bed will be moved to ELETTRA and will be used for in-field trials
- ELETTRA staff will assist the test bed development

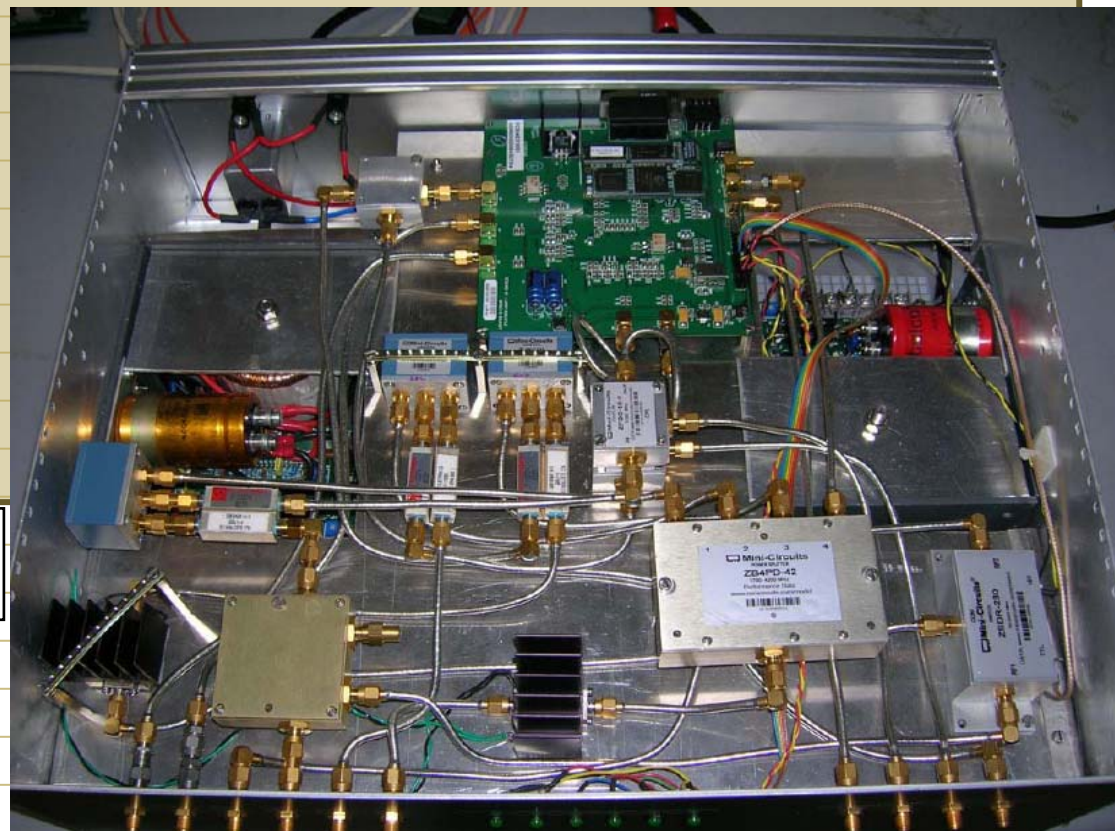
TOS follow-ups …



Courtesy of F. X. Kaertner (RLE-MIT)

TOS follow-ups …

- LBNL is involved in implementing a digital Low Level RF control system
- First tests have been performed on the existing ELETTRA LINAC late last year
- LBNL will develop a system prototype and demonstrate its integration in the ELETTRA LINAC



Courtesy of G. D'Auria (ELETTRA), A. Ratti and L. Doolittle (LBNL)

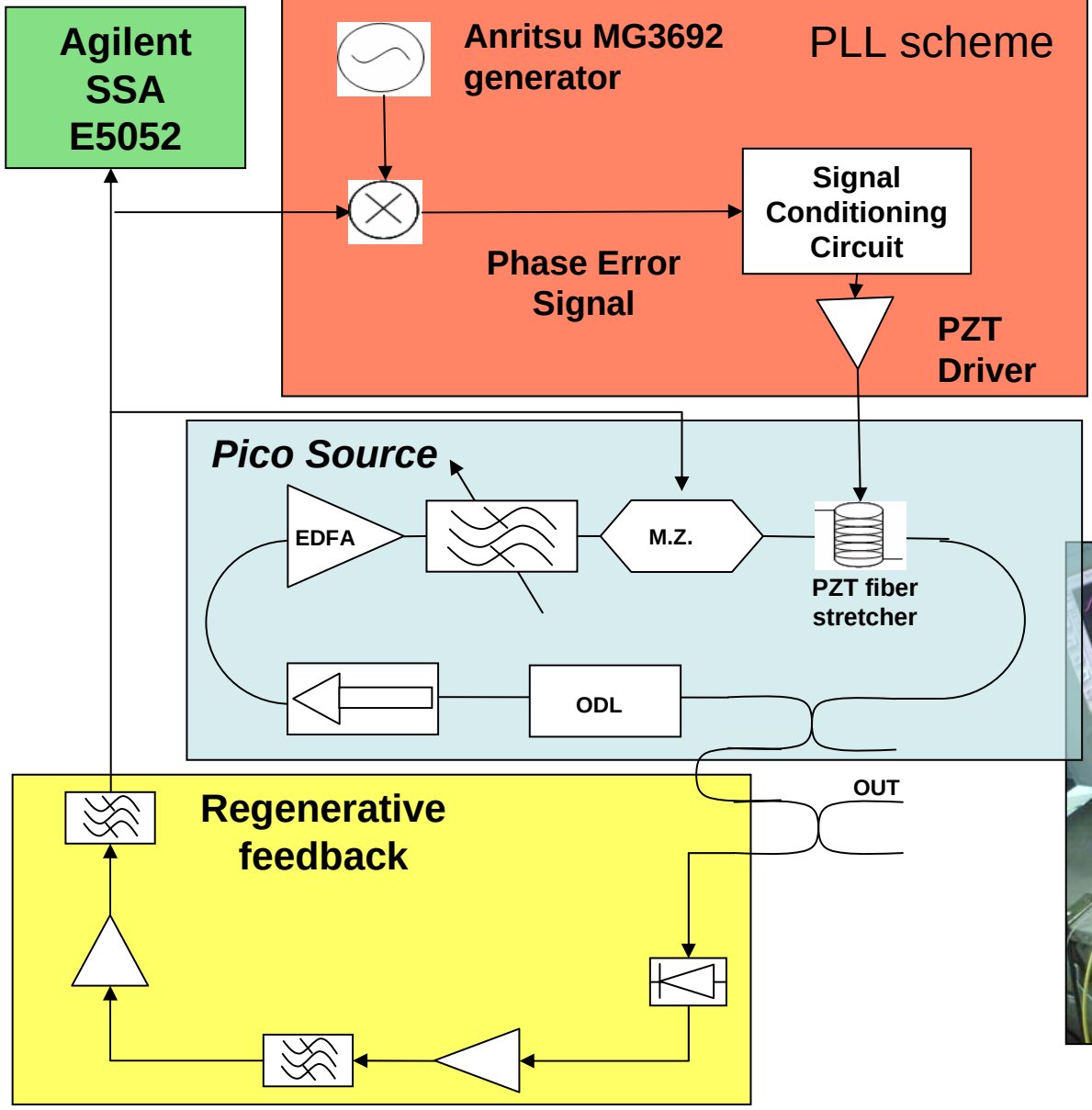
On-going developments at ELETTRA

- Within the frame of EUROFEL DS3, a second test bed will be set-up at ELETTRA to demonstrate the Optical Clock (time domain) concept by using:
  - a fiber laser provided by CNIT and operated at 2.998GHz, named *Pico-Source*
  - internally developed stabilized fiber optics links
  - E/O converters
  - synchronization to a second laser oscillator
- Two young engineers have been recruited for this task:
  - Luca Banchi
  - Fabio Rossi
- A third one will follow soon, to work on “bunch phase”

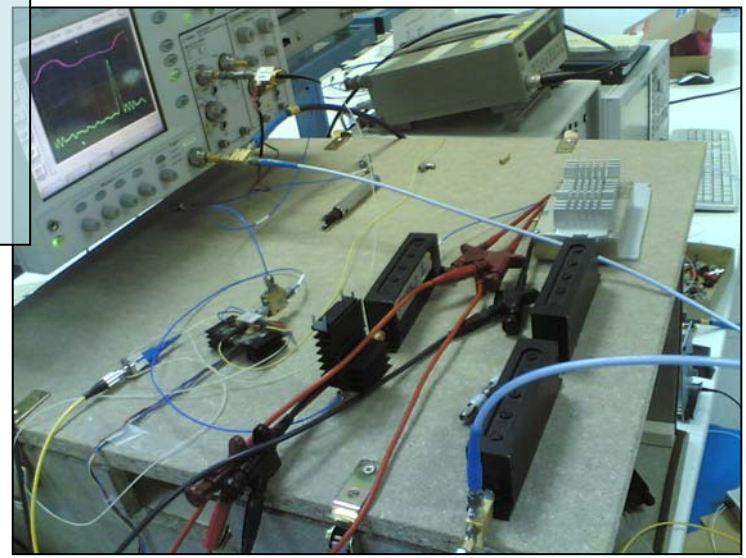
On-going developments at ELETTRA: fiber laser characterization

- In October 2005, preliminary phase noise measurements in the Harmonic ML configuration have been performed at 3GHz:
  - an RMS jitter of **191fs** has been measured in the 10Hz-1MHz frequency interval
- Recently, a new prototype (non temp. stab.) has been operated in Regenerative ML at 2.5GHz, with a PLL to reduce the “low frequency” phase noise
- A Dual Balanced Mixer (DBM) generates the phase error signal between the RF Master Oscillator and the *Pico-Source* repetition rate.
- The phase error signal drives a *Piezoelectric fibre stretcher* to change dynamically the cavity length.
  - The measured RMS jitter has been **122fs** in the 100Hz to 1MHz frequency interval

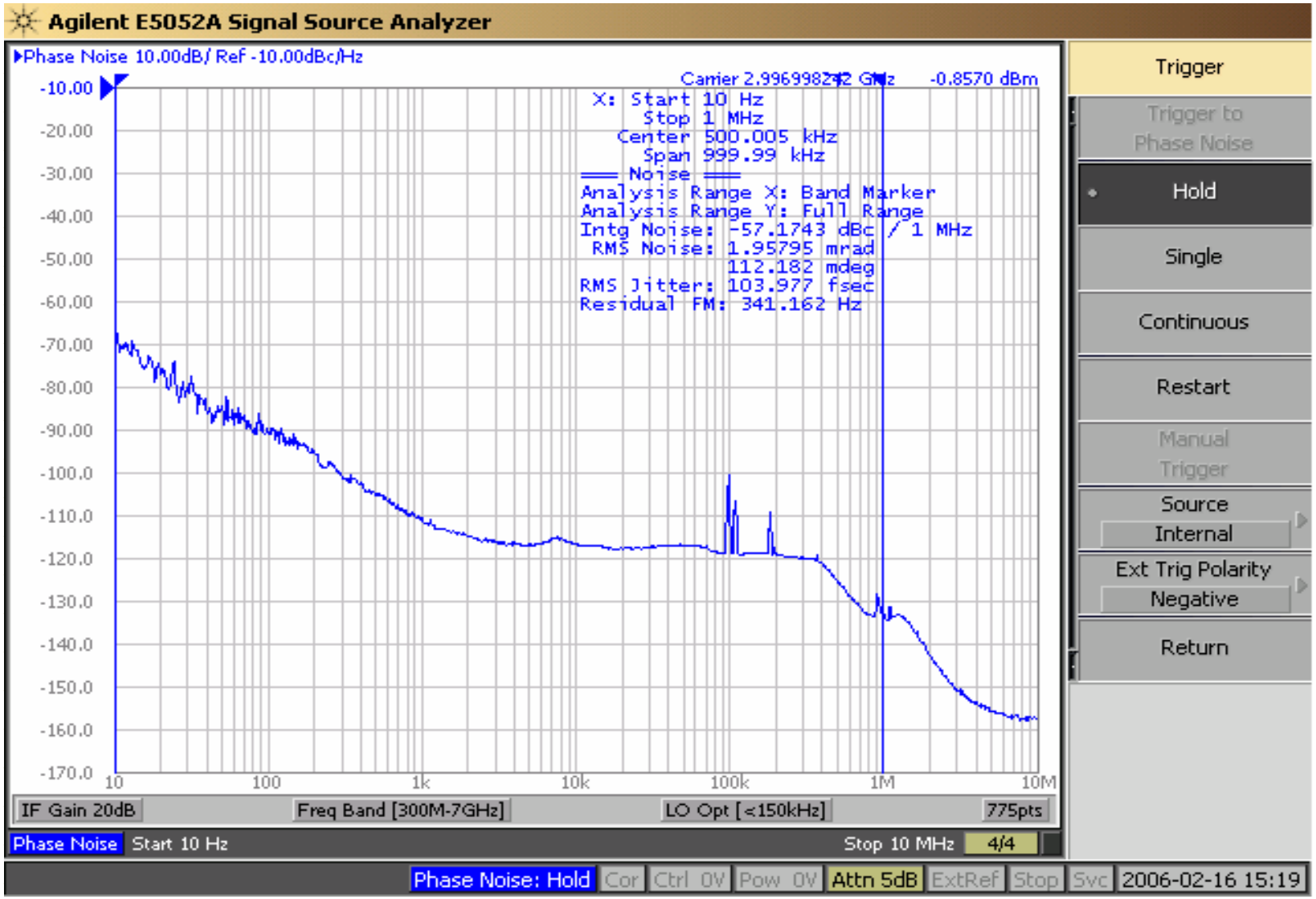
EUROFEL DS3 on-going developments: fiber laser characterization



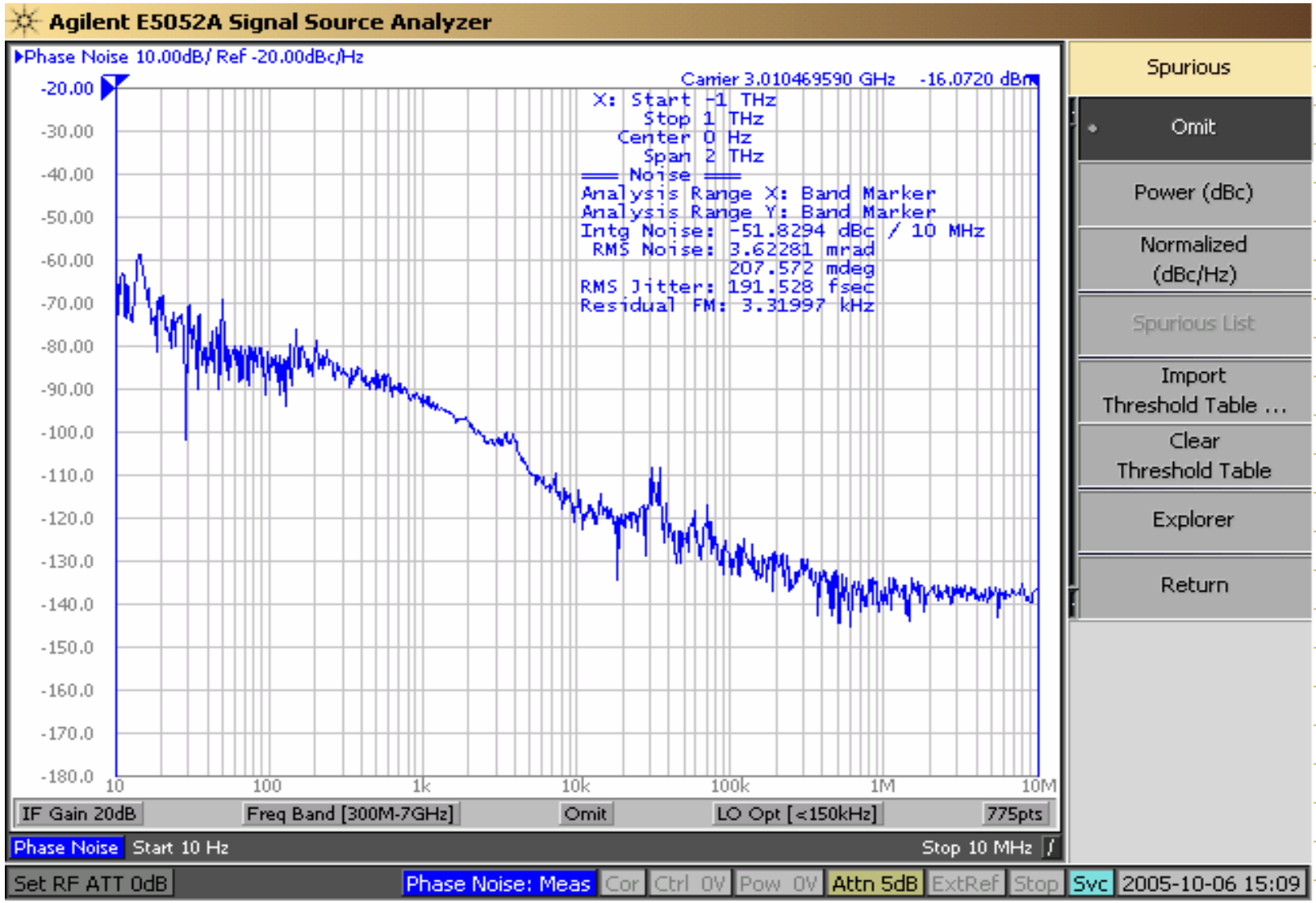
PicoSource in Regenerative ML



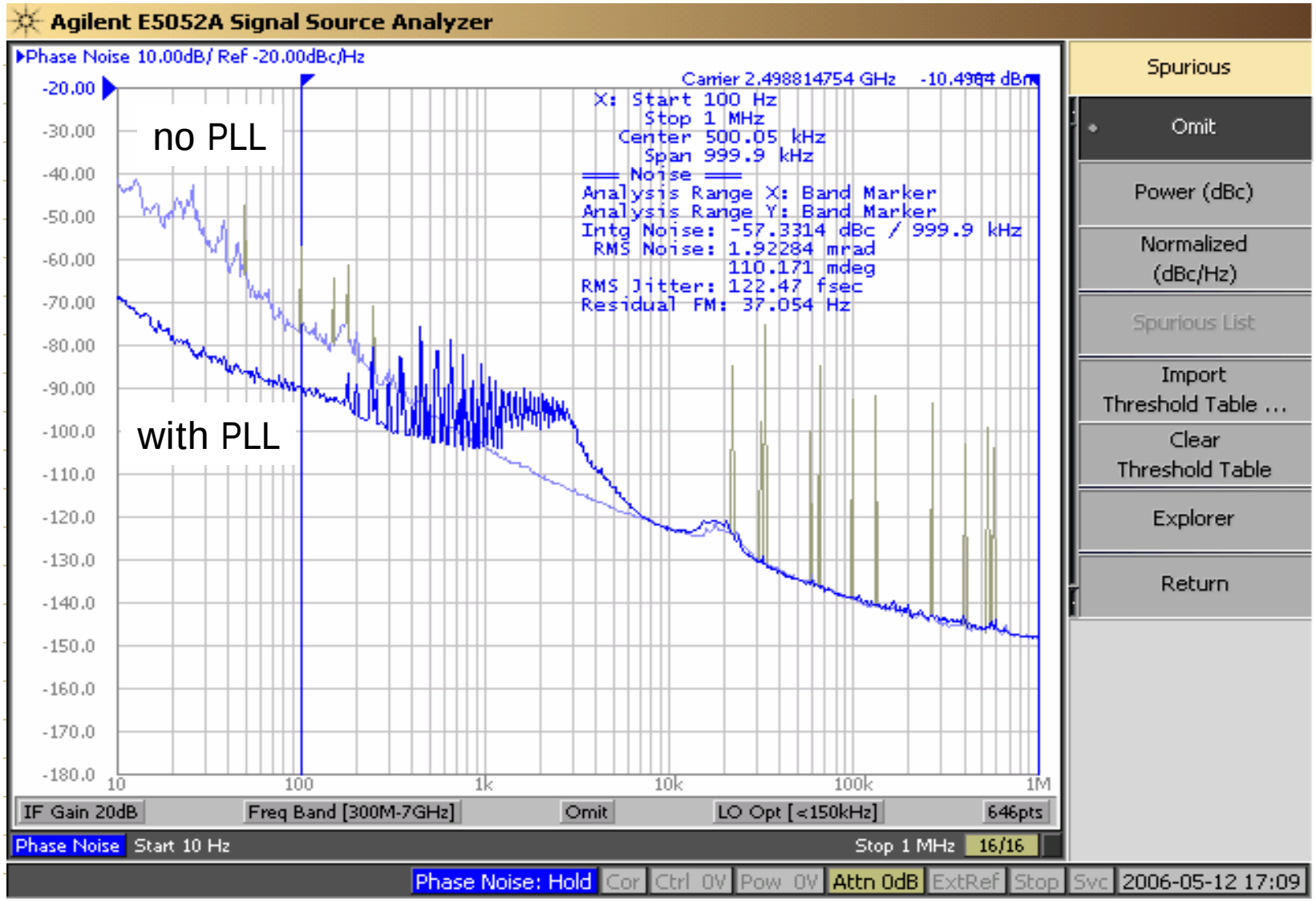
EUROFEL DS3 on-going developments: Anritsu CW generator test (Feb '06)



EUROFEL DS3 on-going developments: Harmonic ML fiber laser tests (Oct '05)

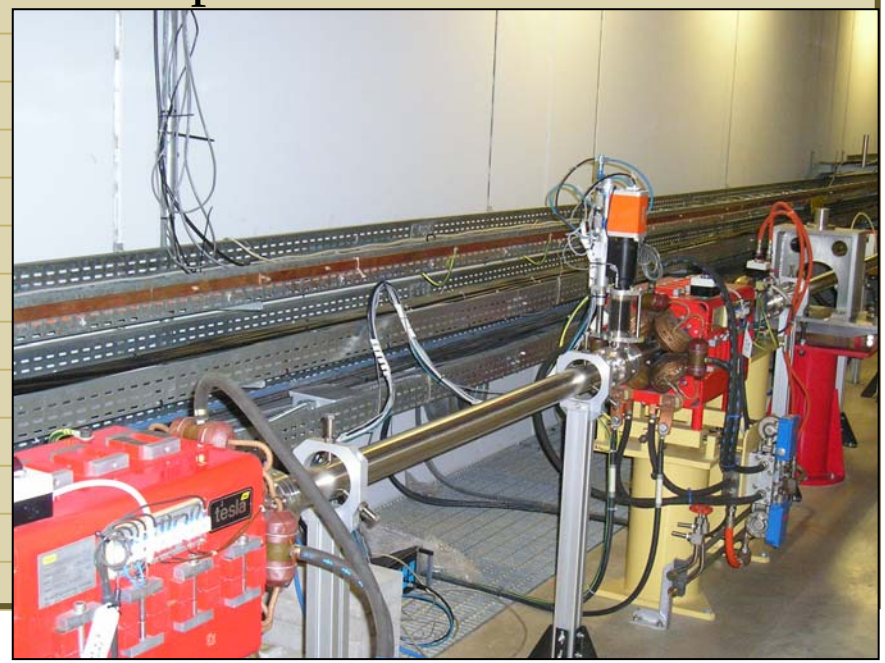


EUROFEL DS3 on-going developments: regenerative ML + PLL fiber laser test (May '06)



On-going developments at ELETTRA: Optical Fiber testing on the ELETTRA LINAC

- the changes in fiber attenuation when it is exposed to the LINAC radiation (both normal and rad-hard fiber)
- the amount of phase noise introduced on the timing signal when propagating inside the LINAC tunnel
- The effects of air perturbations on phase noise
- The FO temperature dependence and the effectiveness of correction schemes



Timing Concepts for the FERMI@ELETTRA facility

Thank you for your attention

Let me here remind you that ELETTRA will host

DIPAC 2007

the European workshop on

Diagnostics and Instrumentation for Particle Accelerator:

you are all kindly invited!!!