HGHG and EEHG seeding at FLASH

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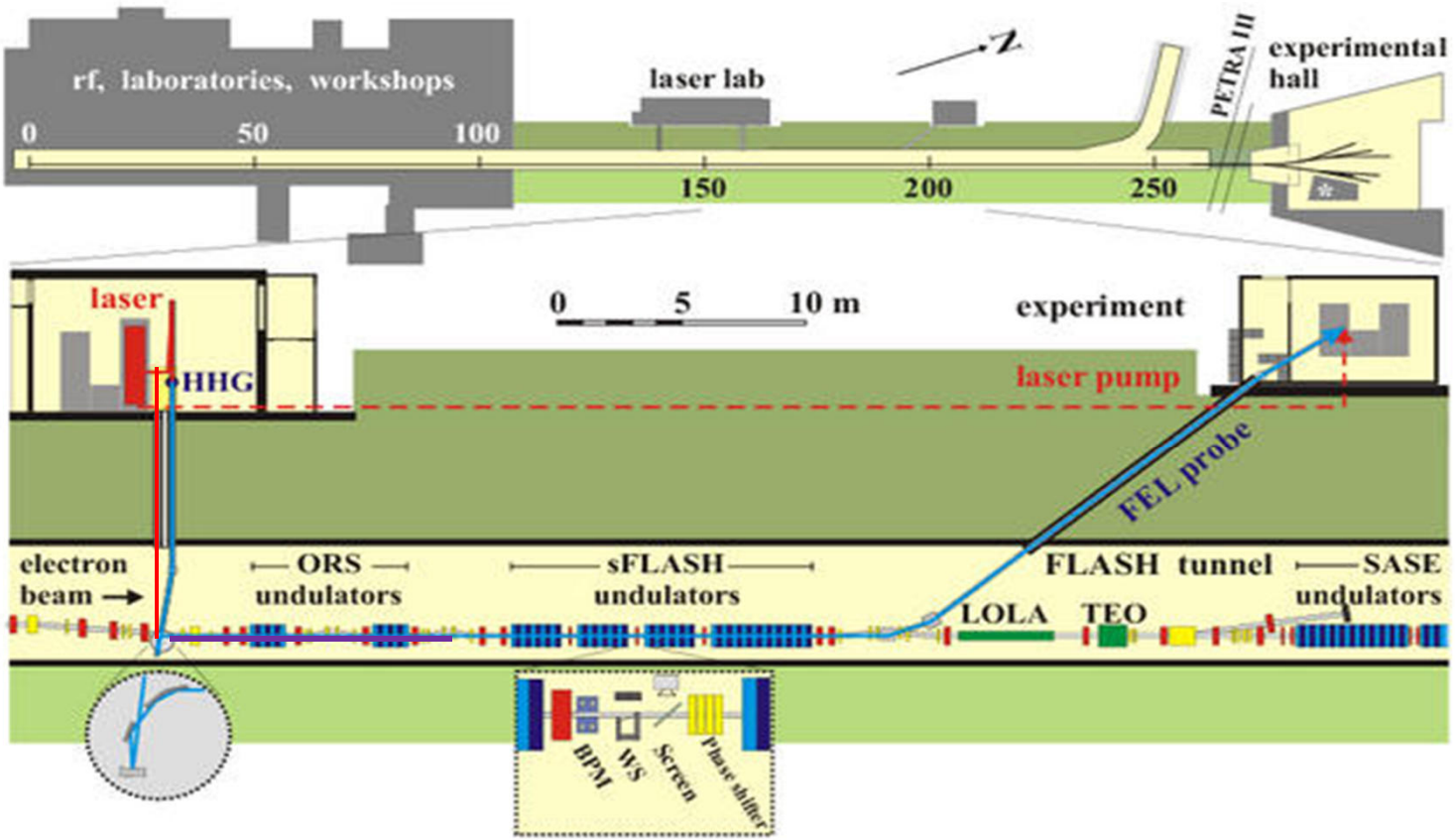
New use for sFLASH infrastructure



- sFLASH HGHG 38.1 nm
- sFLASH EEHG 14 nm
- SASE HGHG cascade 4.7 nm

Project Timeline

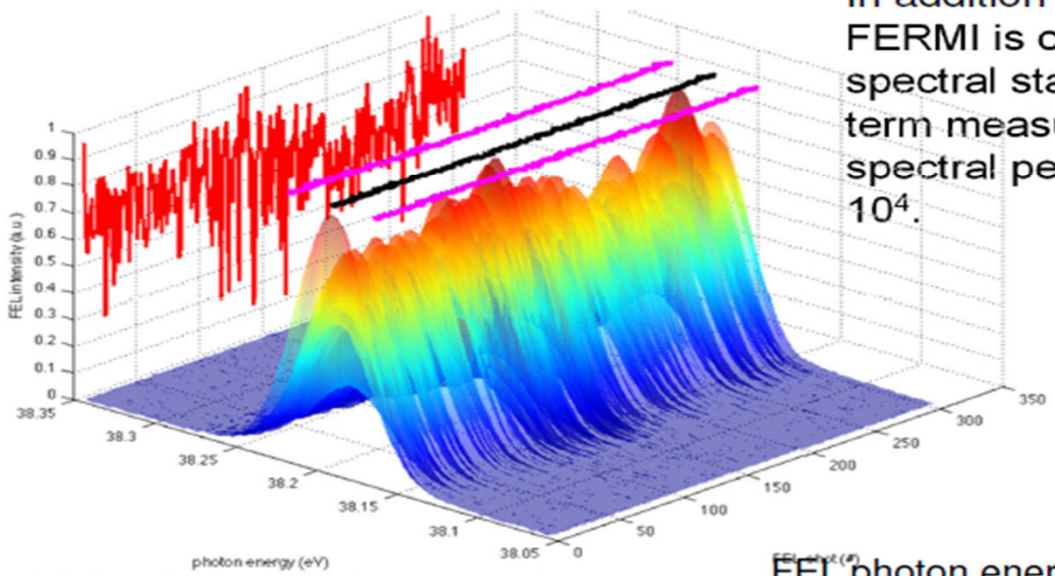
- Jan 2011 proposal to re-commission ORS and try HGHG and EEHG seeding in the sFLASH section
  - Organized collaboration partners
  - Studied tolerances
  - Designed and installed hardware
- Jan 2012 new, 270 nm laser transport infrastructure for ORS, EEHG, and HGHG completed
  - Last mirror was installed upside down
  - Last 2 mirror mounts were not designed with a large enough dynamic range
  - Compressor burnt due to laser malfunction (power supply broke)
- July 2012 270 nm light coupled into e-beamline and overlapped with e-beam within 4 hours
  - sFLASH-HHG infrastructure and experience made this process very efficient
- Sept 2012 expect results from 38.5 nm HGHG seeding
- Nov 2012 last chance at beam-time this year
- Next shutdown upgrade from HGHG to EEHG mode, add diagnostics

2012 : relaxed tolerances, already proven method HGHG at 38.1 nm

- More pulse energy
  - Up to 3 mJ
- Longer seed pulse length
  - 30 fs (FWHM) -> 100 fs (FWHM)
- Larger seed diameter
  - O.5 mm (FWHM) -> 1.5 mm (FWHM)

32.5 nm HGHG at Trieste

FEL wavelength stability



In addition to the very narrow spectrum FERMI is characterized by excellent spectral stability. Both short and long term measurements show that the spectral peak jitter of less than 1 part in 10^4.

Reported data refer to an electron beam of 350pC at 1.24GeV compressed about a factor 3. The 6 radiators are tuned to 32.5nm.

FEL photon energy	~ 38.19eV
fluctuations	= 1.1meV (RMS)
fluctuations	= 3e-5 (RMS)
FEL bandwidth	= 22.5meV (RMS)
fluctuations	= 0.6meV (RMS)
fluctuations	= 3% (RMS)

2013 goal : tighter tolerances, break new ground
EEHG at 14 nm

(19th harmonic of 270 nm)

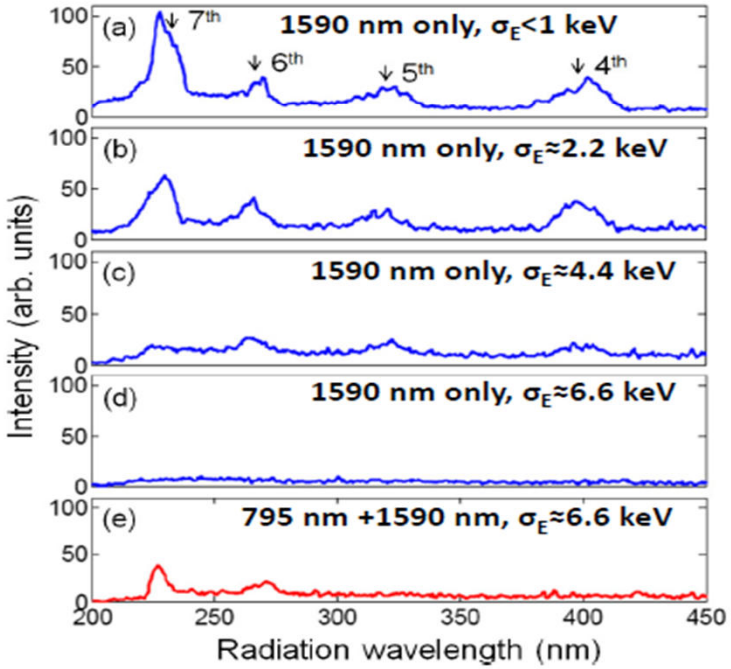
- Longitudinal overlap in 2 undulators
- Smaller seed diameter
  - Tighter overlap tolerances

7th harmonic of 1600 nm EEHG at SLAC

PRL 108, 024802 (2012)

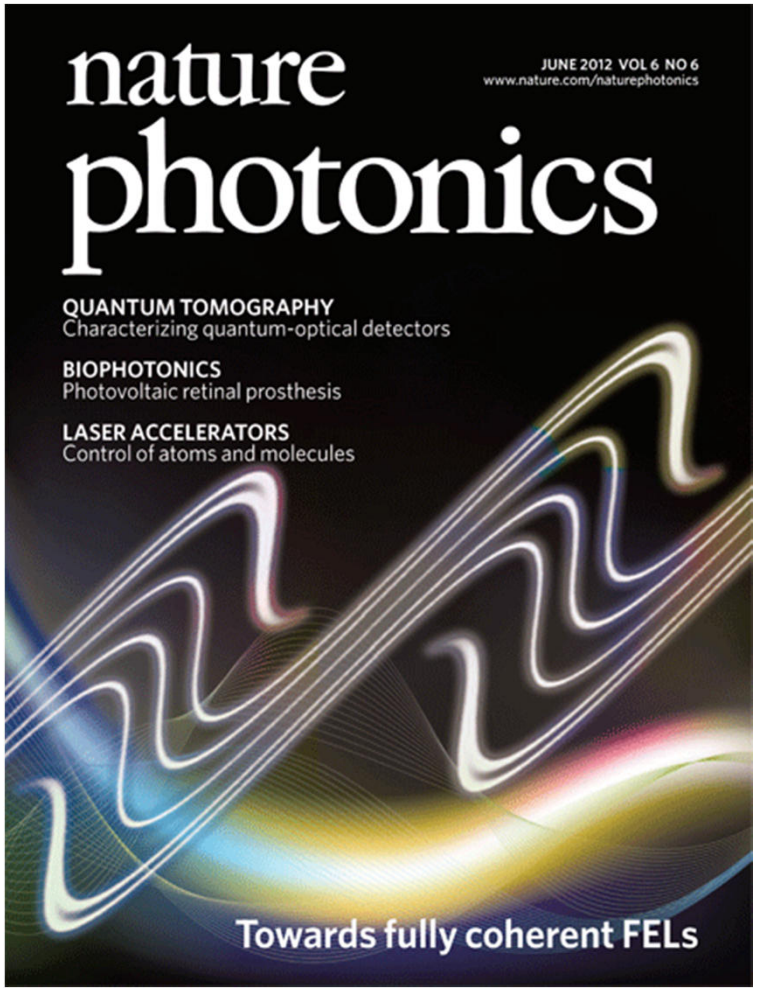
Echo-7: phase-2

- Evidence of high harmonics from EEHG



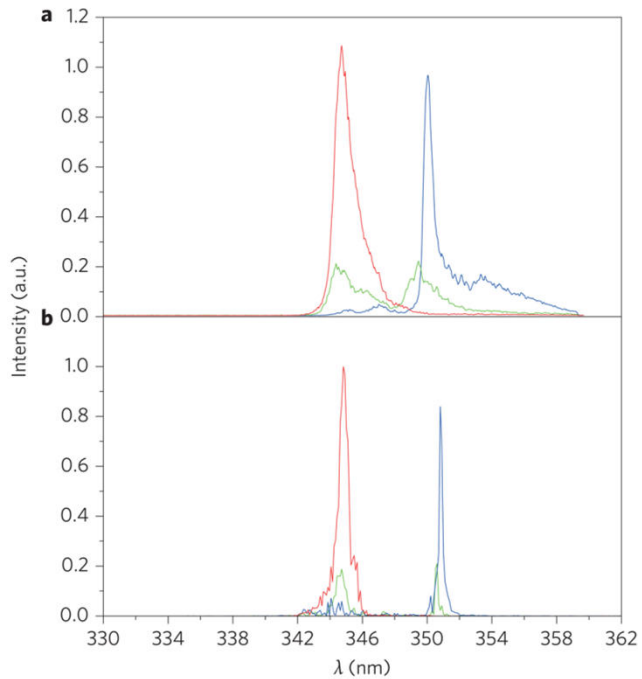
- Two TCAVs and a VUV spectrometer installed in phase-2
- 4th to 7th harmonics from HGHG suppressed with increased beam slice energy spread
- 7th harmonic generated with the first laser on
- 7th harmonic from EEHG generated when energy modulation is about 2~3 times the beam slice energy spread

3rd harmonic of 1050 nm EEHG at SINAP

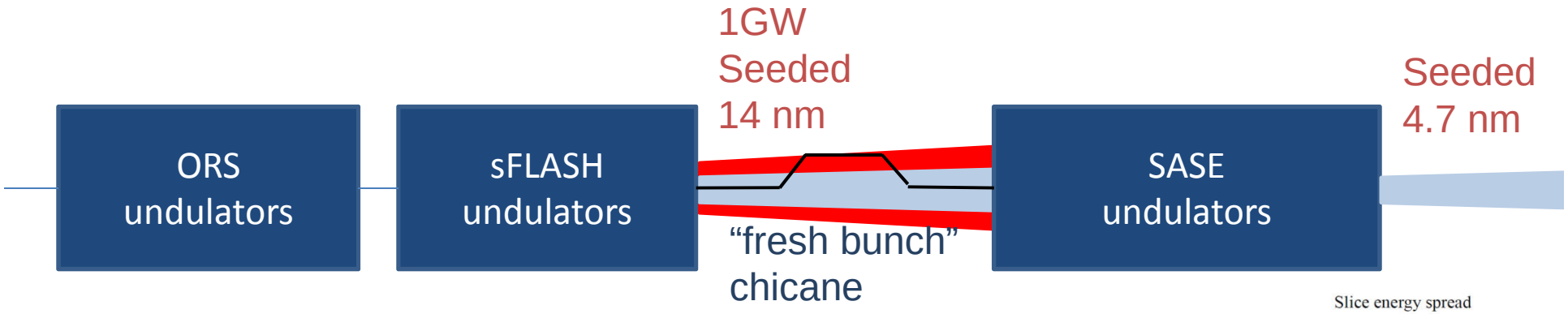


June 2012 cover

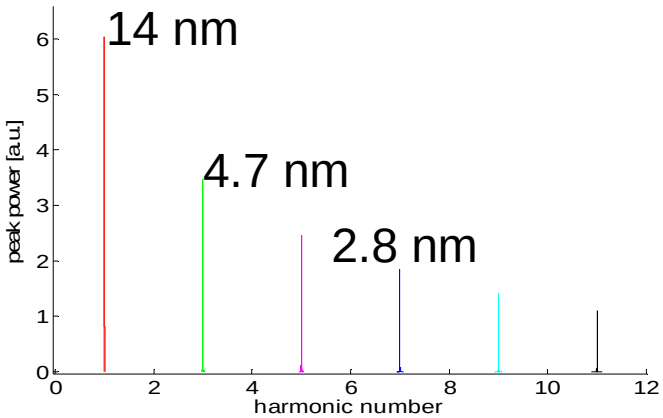
- Compared to HGHG, EEHG has a lower sensitivity to electron beam energy chirp
- Transition between HGHG and EEHG, easy to see on spectrometer

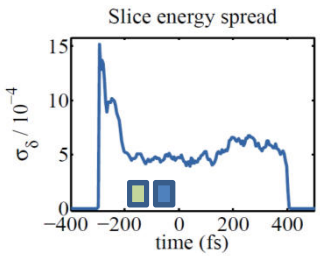


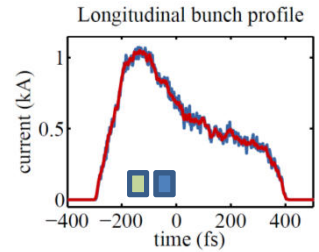
2014 goal : use sFLASH radiation to seed SASE undulators at 4.7 nm



Fresh bunch technique
OR
Super-radiant regime



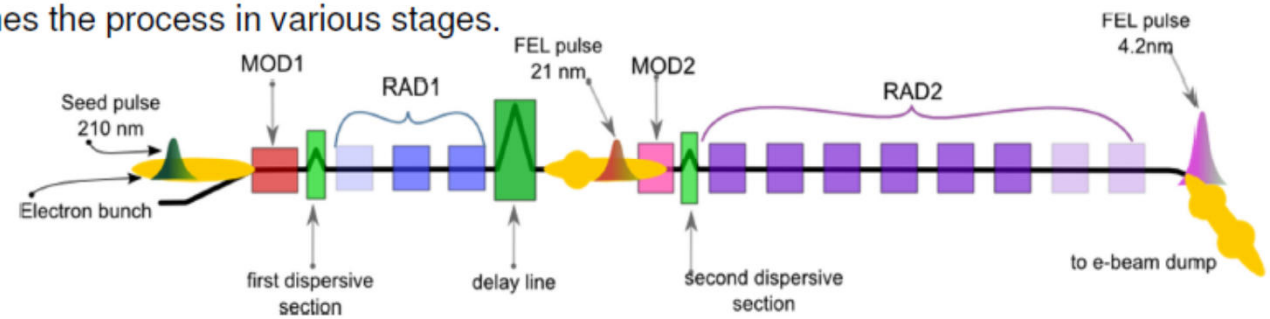




4 nm HGHG cascade at Trieste scheduled for commissioning now

The HGHG cascade

A way to **really extend the HGHG** to **higher harmonics** (50th-100th) is to **repeat** several times the process in various stages.



In a **two stages HGHG cascade FEL**, the **first stage** can allow to generate a FEL pulse at about **20nm** starting with a seed laser at 200nm.

The produced **FEL pulse at 20nm** is then used as a **seed in a second HGHG** stage allowing to **create bunching** and have the FEL operating at about **4 nm**.

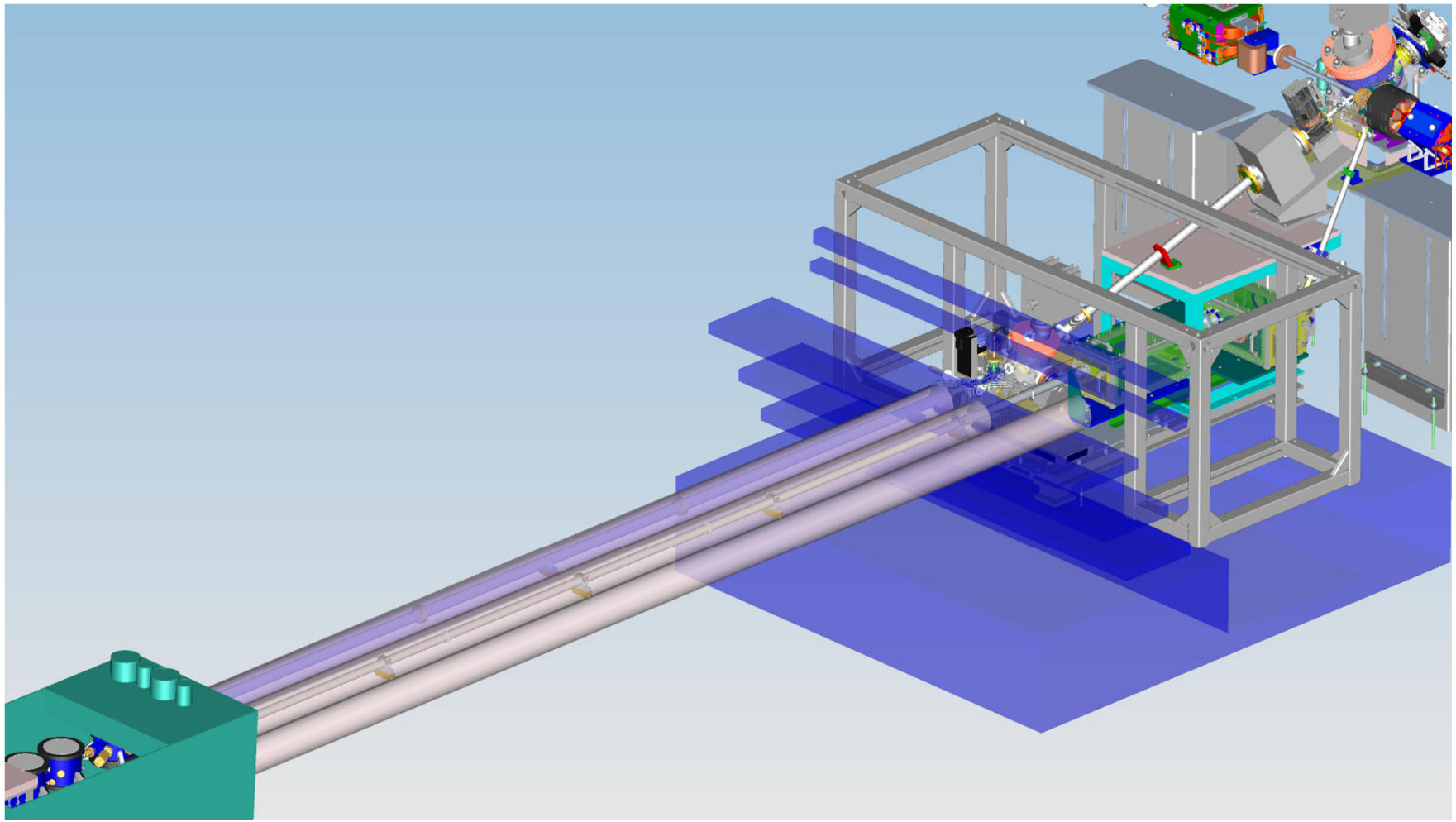
The "fresh bunch" technique is used to have the seeding always occurring in a part of the electron beam that has not been spoiled by previous FEL interaction.

With a three stages HGHG cascade it is possible to go to the 1 nm spectral range.

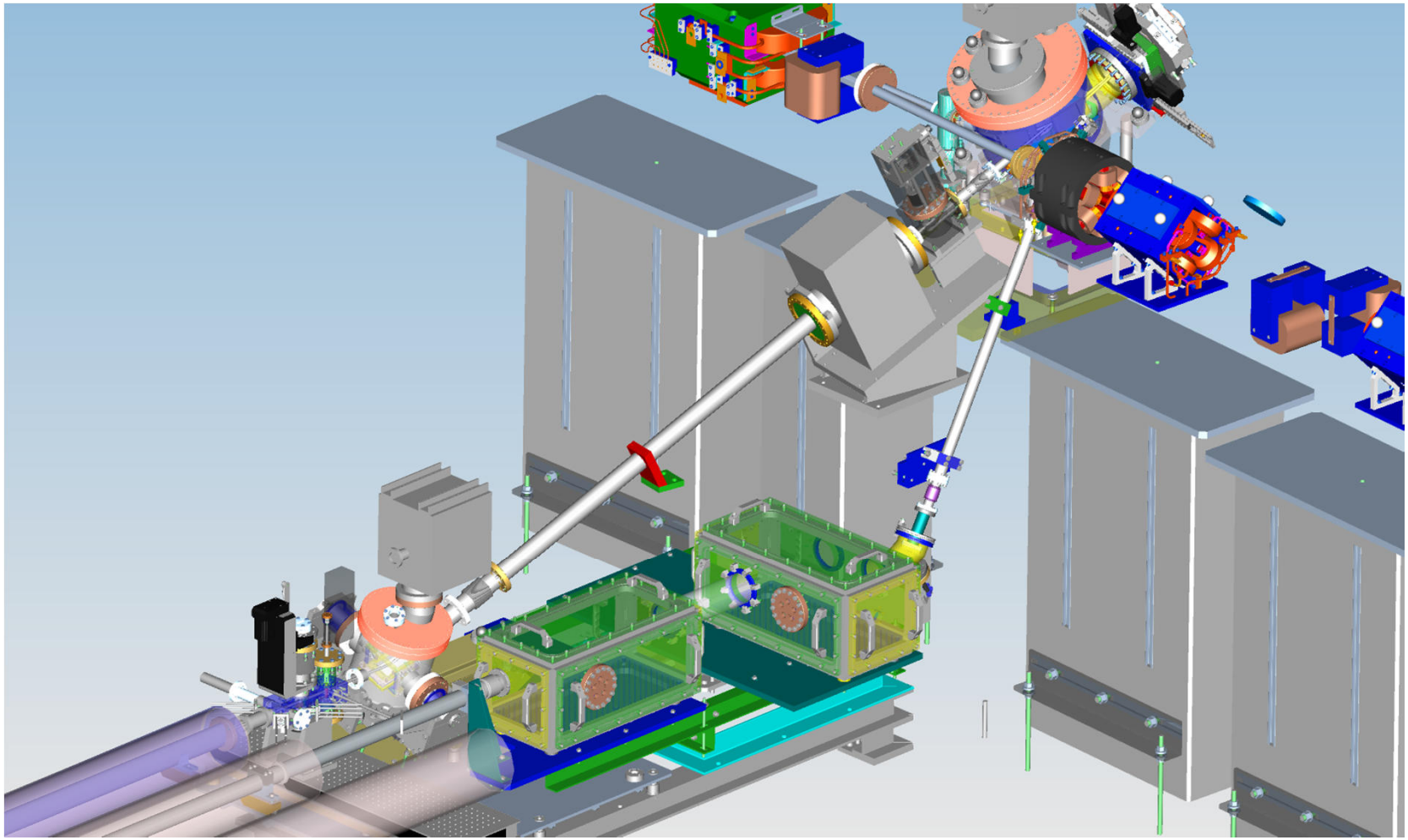
Studies to experimentally demonstrate the cascaded HGHG recently started at SDUV-FEL and will begin at FERMI in mid 2012.

Slide from Allaria

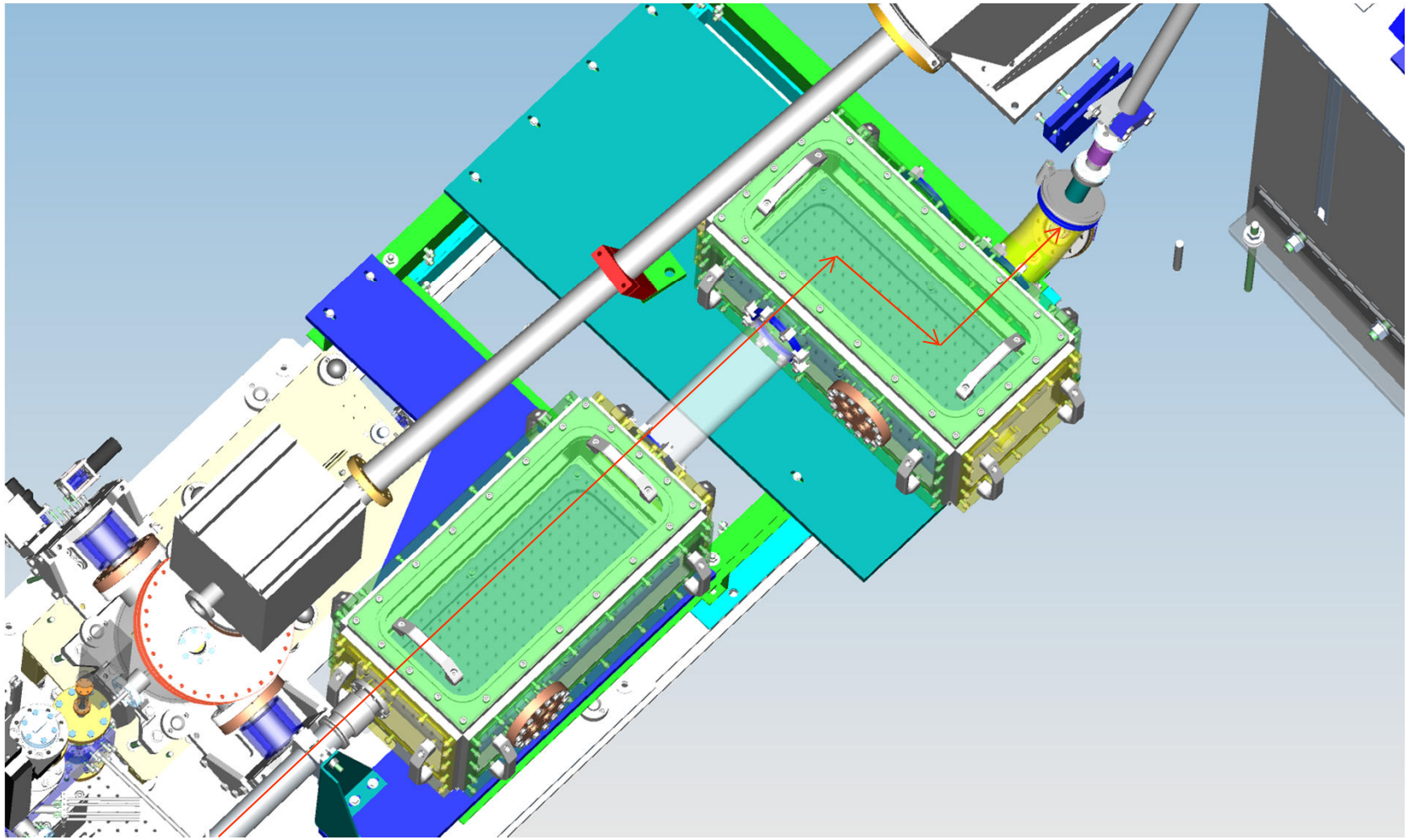
Laser Transport Line



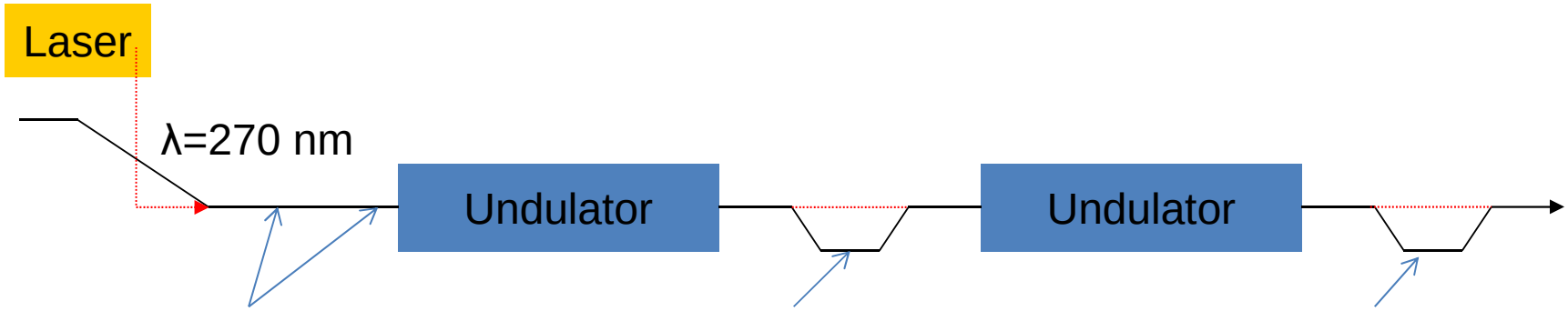
Laser Transport Line



Laser Transport Line



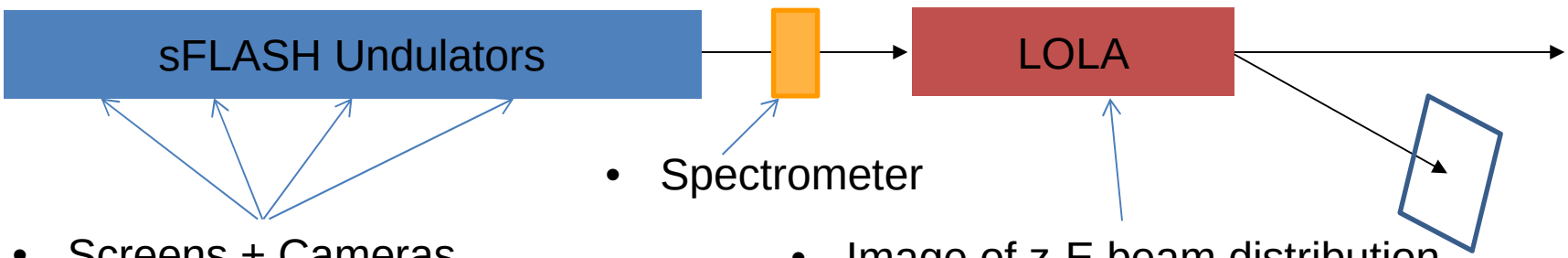
ORS/sFLASH Section Diagnostics



- Screens + Cameras

- Spectrometer
- Streak camera
- Photomultiplier tube
- Screens + Cameras

- UV-TG FROG (NEW)
- UV Photodetector
- Screens + Cameras

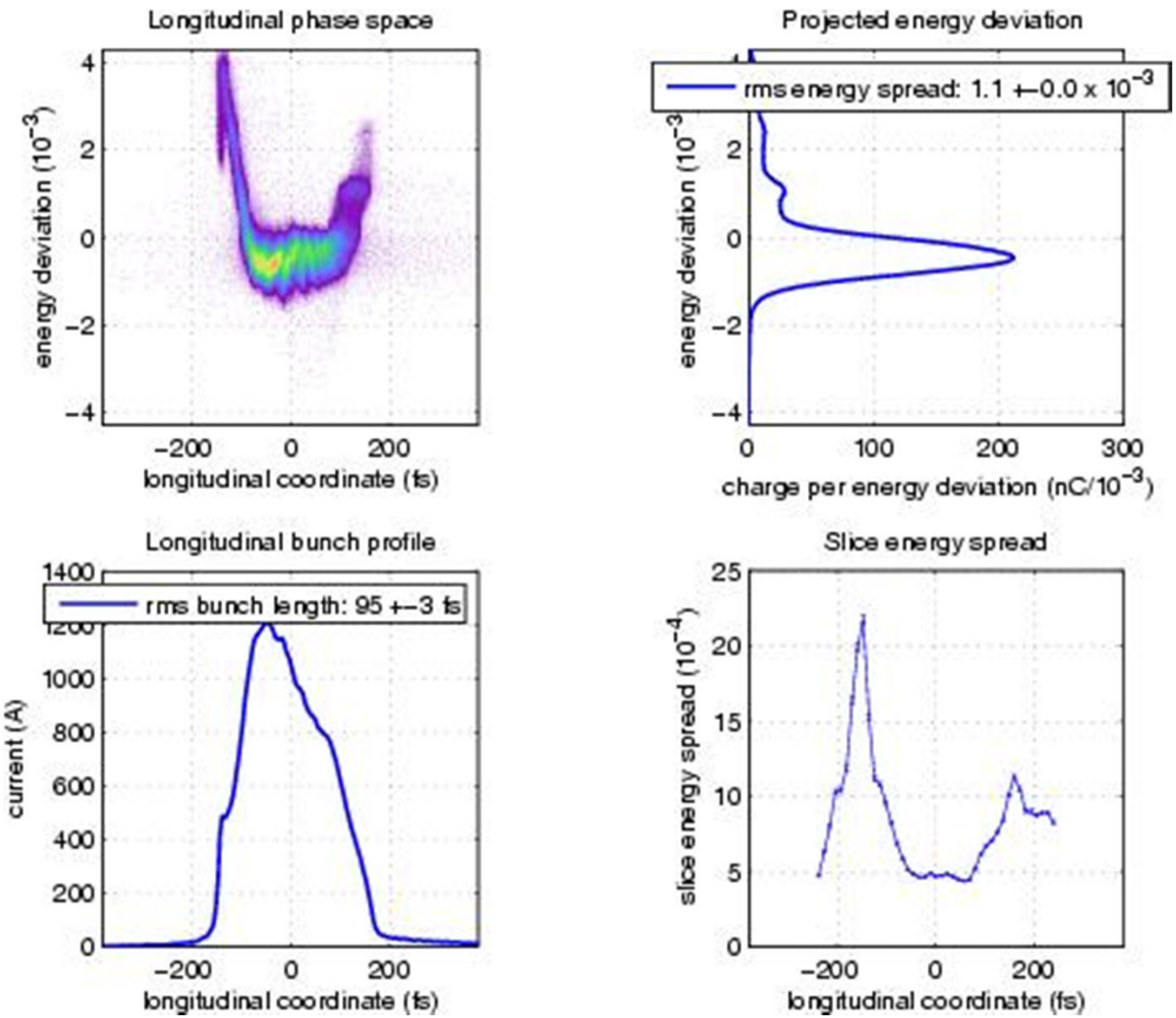


- Spectrometer

- Screens + Cameras

- Image of z-E beam distribution with ~100 keV, 10 fs resolution

Advantage: LOLA



Advantage: FROG

Directly measure seed spectrum and spectral phase
i.e. longitudinal pulse form

See next talk (Dongjoo Lee)

Accomplishments so far

- Easy incoupling of laser, near-field detector operational
- Transverse and longitudinal overlap with electron beam achieved in <4 hrs on first try
- Looked for evidence of modulation on LOLA and through COTR from second ORS undulator but didn't see it
  - Spot size and polarization were not optimal
  - Pulse length too short to see easily, tripling efficiency needs another look

Next shift

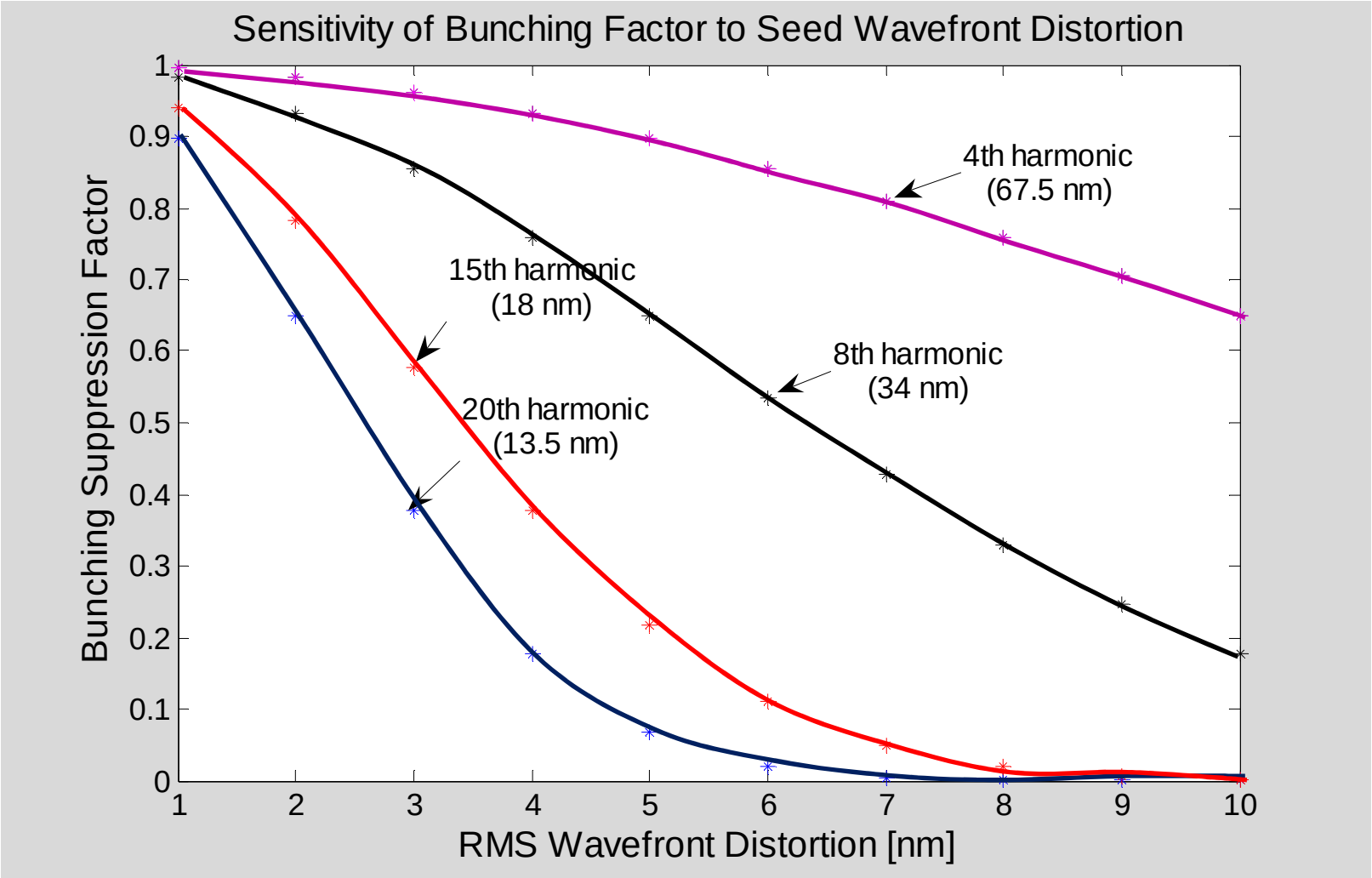
- Laser pulse will be longer and have a higher pulse energy
- Laser waist will be tuned for easier overlap
- Polarization will be optimized
- LOLA software will make seeing effect easier

- We will demonstrate HGHG seeding at 38.1 nm

New diagnostics in preparation

- UV TG FROG
  - Measure spectrum and spectral phase of 270 nm seed pulse
  - Arrived today (see next talk from Dongjoo Lee)
  - Initial tests in Dortmund laser lab
  - Final installation in optical station 2 of the ORS section scheduled for beginning of 2012
  - Possible use in parasitic ORS and EO experiments.
- Far-field detector housing constructed, beam out-coupling window corrected, just needs a camera and screen
  - To be used for wavefront tuning

Wavefront distortions: biggest problem for higher harmonics



Summary

- 2011 Experiment proposed and designed
- 2012 HGHG seeding at 38.5 nm (Sept, Nov)
- 2013 EEHG seeding at 14 nm
- 2014 HGHG cascade at 4.7 nm
- Almost all hardware has already been purchased, off-site advisers and helpers are plentiful, but on-site person-power is limited