DS4 – Summary and Perspectives

Cockcroft institute, Daresbury, 7 November 2006

Where are we?

- Results (or problems)
- Building up (or delayed)
- Recruited (or too few)
- Funded (or too little money)

- > 30 Publications (25 Conference contributions + 7 Articles)

Inducing strong density modulation with small energy dispersion in particle beams and the harmonic amplifier free electron laser
Simulating HGHG with Genesis 1.3 – An unofficial guide
Inducing strong density modulation with small energy dispersion in particle beams and the harmonic amplifier free electron laser
4GLS Free Electron Lasers
Status of the Seeding Experiment at Sparc
Harmonic lasing in an FEL amplifier
Ultra-short Pulses from Super-radiant Seeded FEL
Seeding with HHG
Progress over the year - mainly harmonics
Seeding the FEL at SPARC facility
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Design of an improved pre-injector for the MAX linac
Studies of bunch compression in the MAX-lab recirculator system
A Seeded HGHG Test Bench at MAX-lab
Ideas for Bunch Length Measurements at MAX-lab
Harmonic generation using the Elettra SRFEL optical klystron
Overview of the SPARC FEL experiment
Seeding and harmonic generation in Free Electron Lasers
Future seeding experiments at SPARC
Undulators for a Seeded HGHG-FEL Test Bench at MAX-lab
MEASUREMENTS AND DIAGNOSTICS ON THE MAX RECIRCULATOR
DESIGN OF A NEW PREINJECTOR FOR THE MAX RECIRCULATOR TO BE USED IN EUROFEL
SIMULATIONS FOR THE FEL TEST FACILITY AT MAX-LAB WITHIN EUROFEL
High harmonic seeding and the 4GLS XUV-FEL’,
Simulation studies on the self-seeding option at FLASH

Simulation of emission and propagation of coherent synchrotron radiation wave fronts using the methods of wave optics
The harmonically coupled 2-beam FEL’
Status of the Seeding Experiment at Sparc
Inducing strong density modulation with small energy dispersion in particle beams and the harmonic amplifier free electron laser
Harmonic lasing in an FEL amplifier
The Harmonic cascaded FEL
Harmonic Lasing in a Free-Electron-Laser Amplifier

9.00 Introduction, Mid term review, issues for the GA and PSC, *Sverker Werin*

9.15 Lab status/ reports/issues/questions
(1-2 presentations à 15 min per subtask)

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Marie Labat CEA/SOLEIL
Luca Giannessi ENEA

DS 4.4 Seelf seeding technique
Velizar Miltchev UNIHH/DESY

DS 4.5 Physics issues and model development for ERLs
Neil Thompson USTRAT/CCLRC

Refreshment break

DS 4.2 Harmonic generation of sub ps and fourier limited pulses
Mauro Trovó ELETTRA/ENEA

DS 4.1 First stage of harmonic generation
Johannes Bahrdt, BESSY
Sverker Werin, MAX-lab

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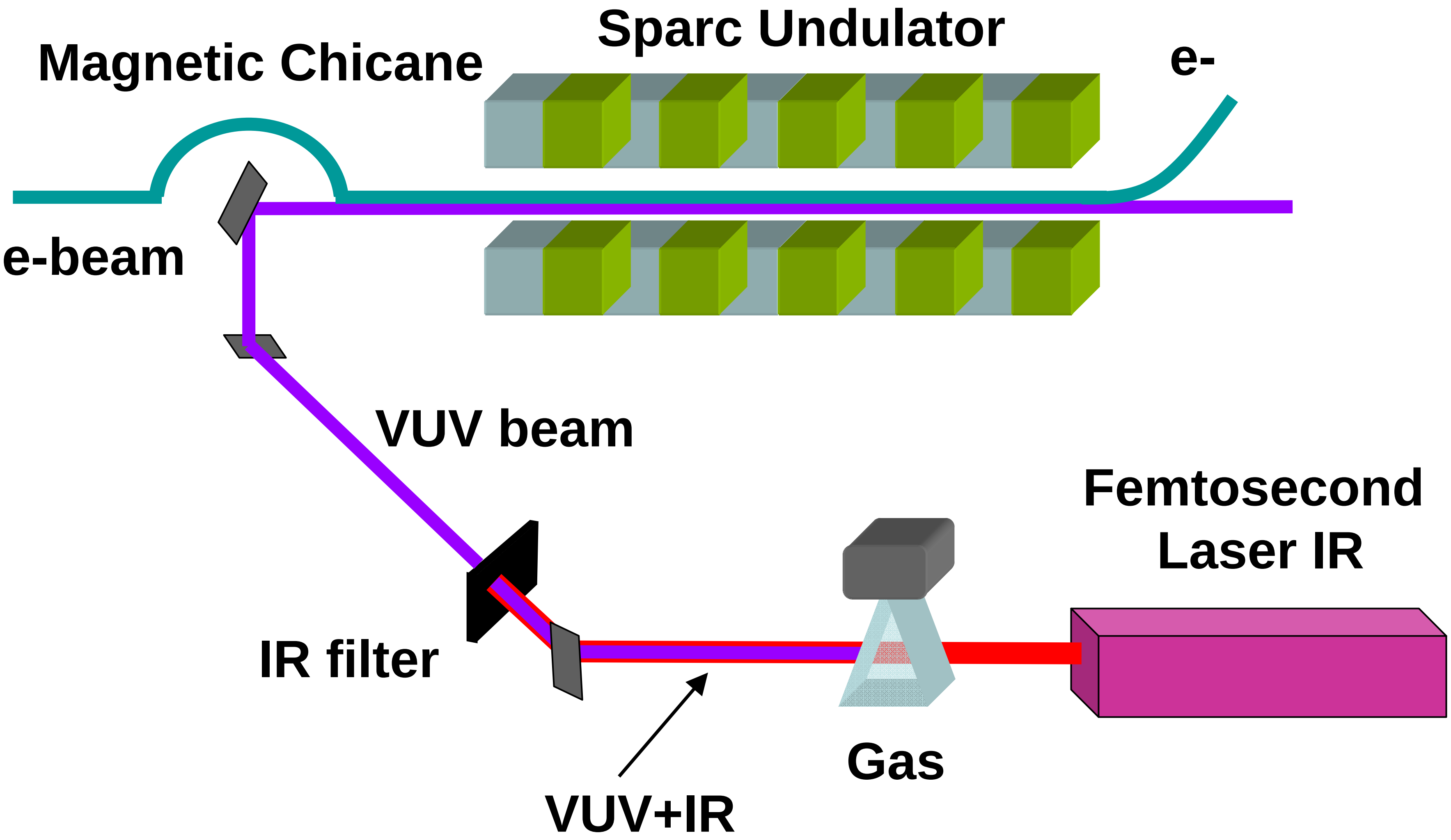
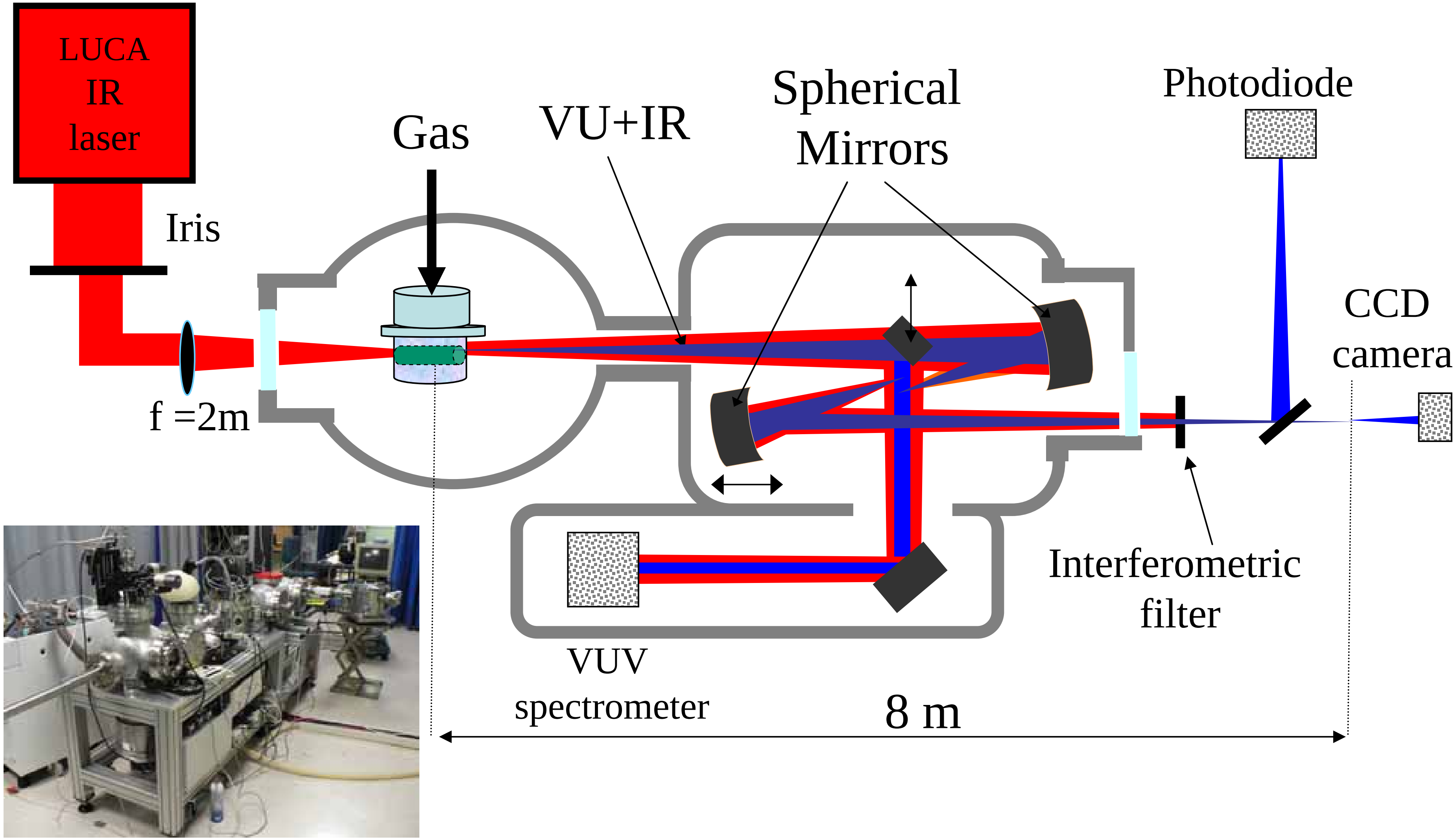
Marie Labat

General Layout



Seeding Chambers



GENESIS under SRW

- Equation of motion setting the dynamics of the electrons used in Genesis 1.3

  → Implemented in SRW

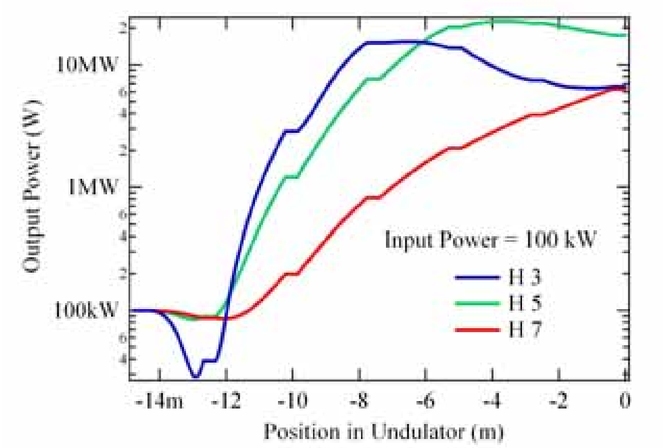
- Equation of evolution of the electric field inside the undulator used in Genesis 1.3

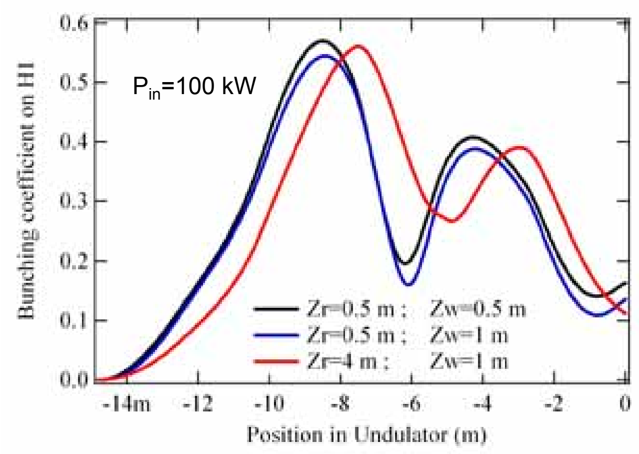
  → Implemented in SRW

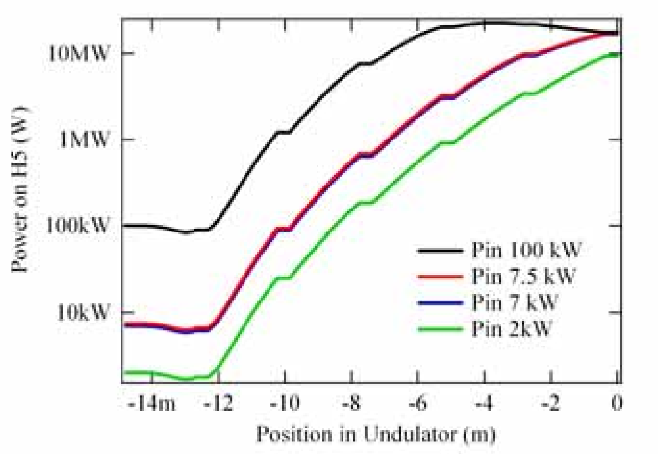
- Wave front propagation of the seed and/or the output FEL radiation by SRW

Tests on SPARC example

- Seeding with HoHG (H3/5/7):
  - Saturation Length
  - Saturation Power
  - Influence of the seed focusing



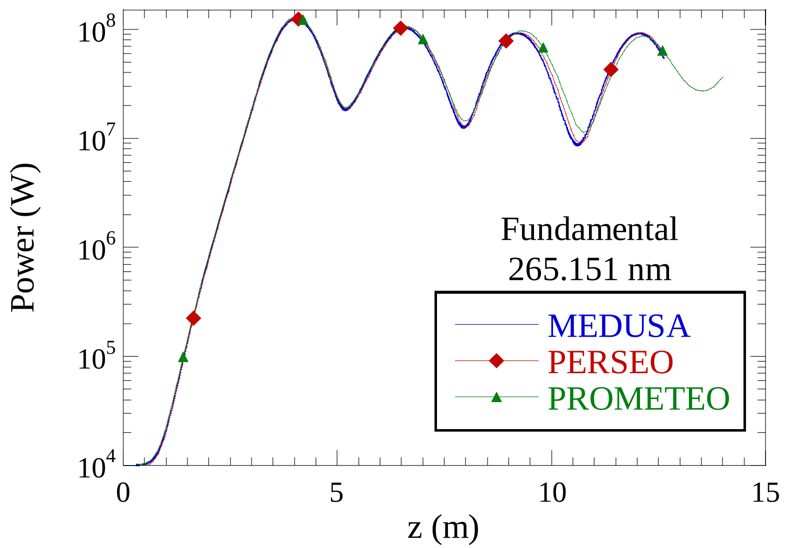


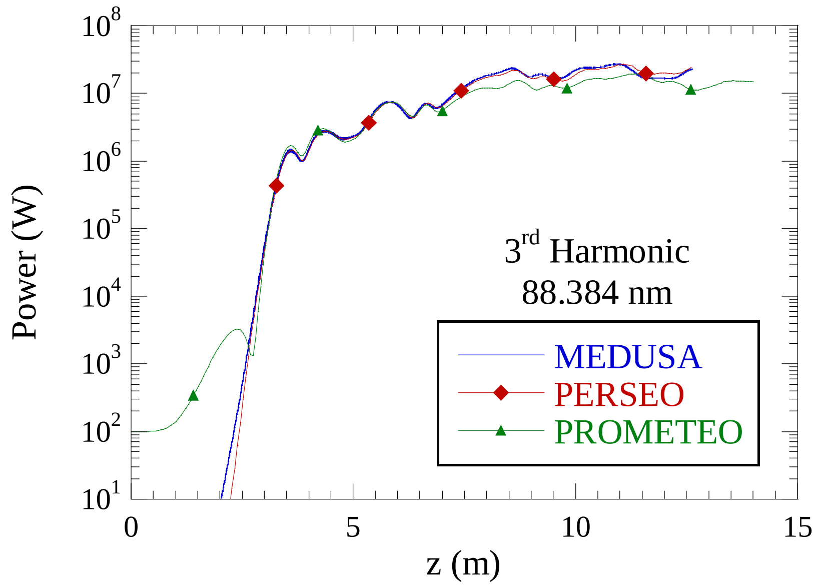


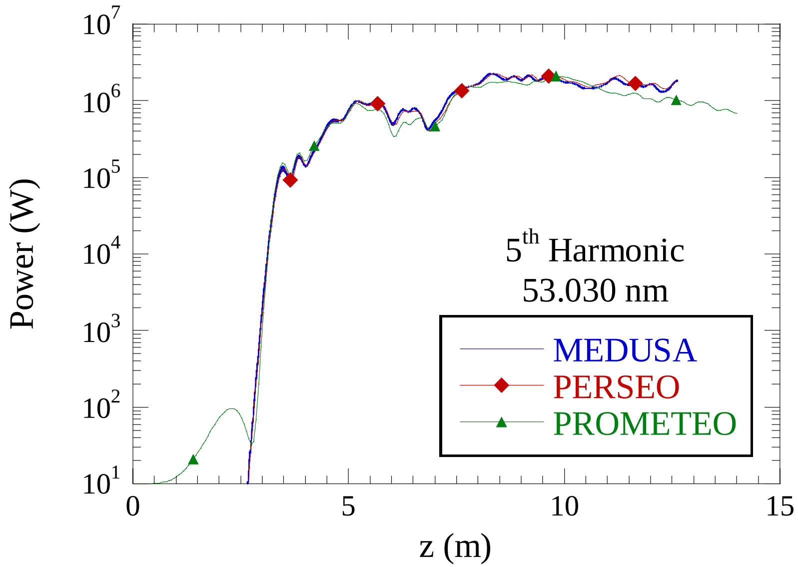
<u>E- Beam Parameters:</u>

- E = 200 MeV
- σ_γ = 0.2 %
- σ_e =1 mm-rms
- I =100 A
- ε = 5.11 nm.rad

Results - 1D Code Comparisons for SPARC

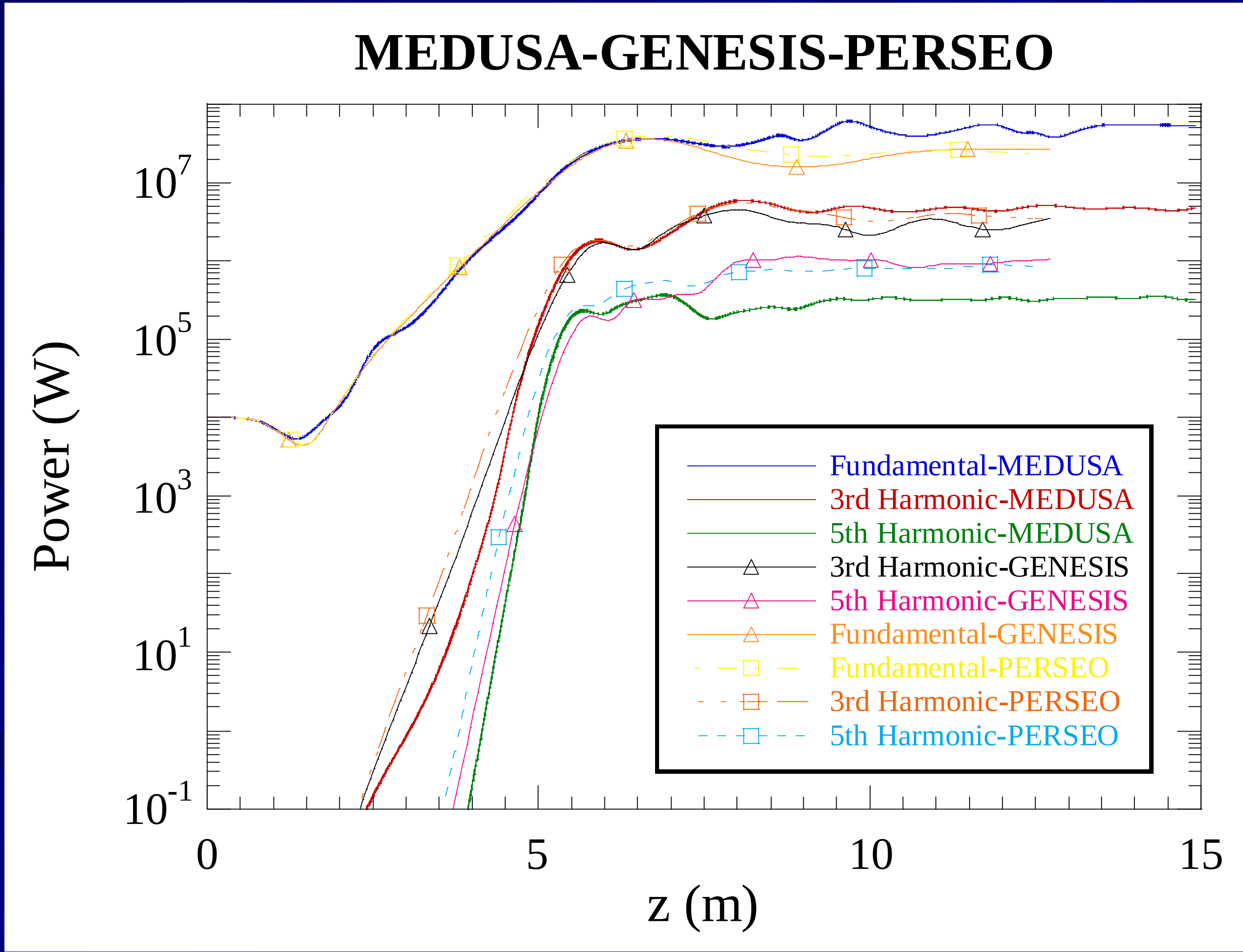






Luca Giannessi

Code comparison II
MEDUSA - GENESIS - PERSEO 2D



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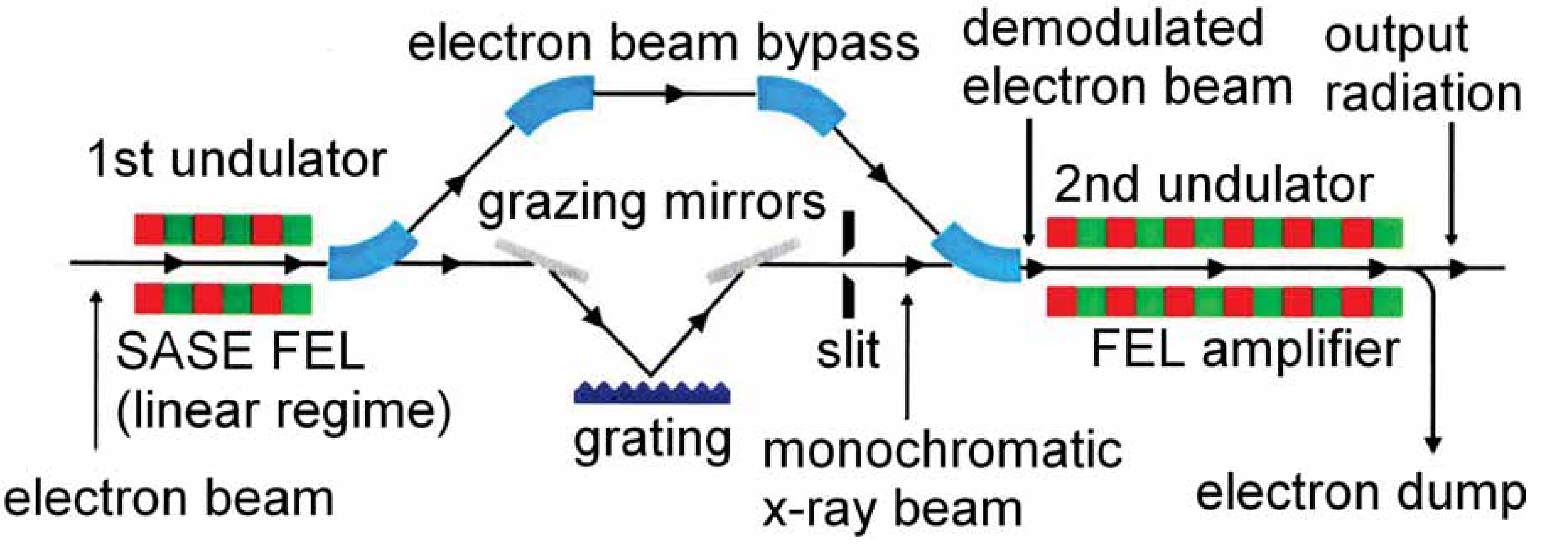
Basic principles of the self-seeding option

J. Feldhaus et al. / Optics Communications 140(1997) 341-352



Schematic view of the self-seeding option at FLASH

- The 1st section operates as a SASE FEL in linear regime
- After the bypass the micro bunching is reduced by a factor of $\exp(-\sigma_\delta^2 k_L^2 R_{56}^2 /2)$
- The monochromatic photon beam is used as a seed in the 2nd section
- The seeding power P_{SEED}~10kW >> shot noise power $P_{SHOT} \leq 100W$
- The seed pulse is amplified to saturation in the 2nd undulator section

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Neil Thompson

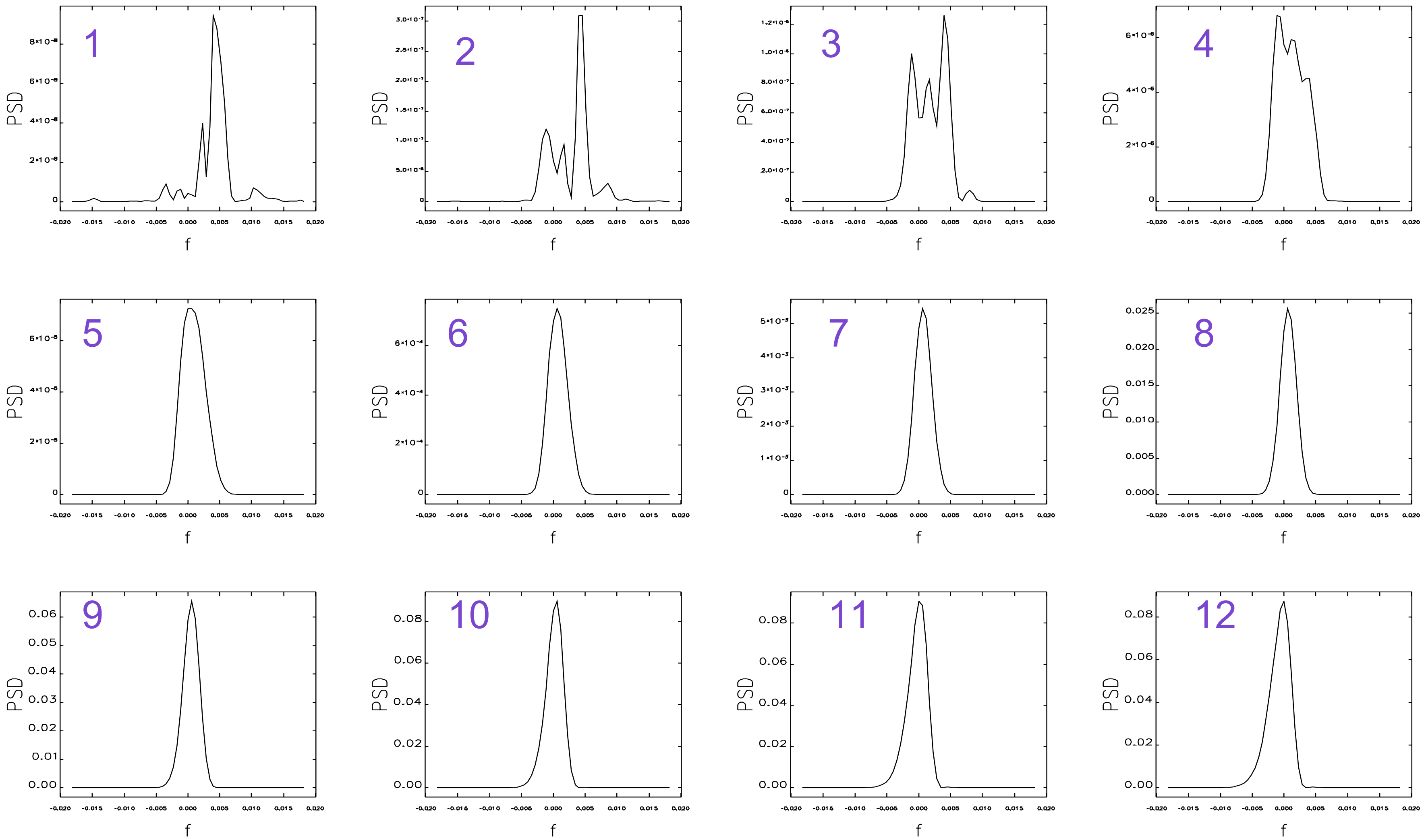
Regenerative Amplifier FEL
The Concept and relevance to 4GLS

- Gain is very high (~10,000%) -
  - *Low reflectivity optics OK*
  - *Large outcoupling to maximise output power*
- Cavity Q is low and gain guiding of FEL interaction dominates -
  - *Cavity just provides a seed pulse for next pass*
  - ***The RAFEL is a self-seeded amplifier FEL, not an oscillator FEL***
- Electron beam shot noise averaged out → *good longitudinal coherence*
- The 4GLS VUV-FEL requirement: *temporally coherent FEL pulses over 3-10 eV range (where only low reflectivity optics are available)*

→ ***a RAFEL seems the ideal solution***

Neil Thompson

1D TD Simulations:
Spectral development (0.4μm detuning)



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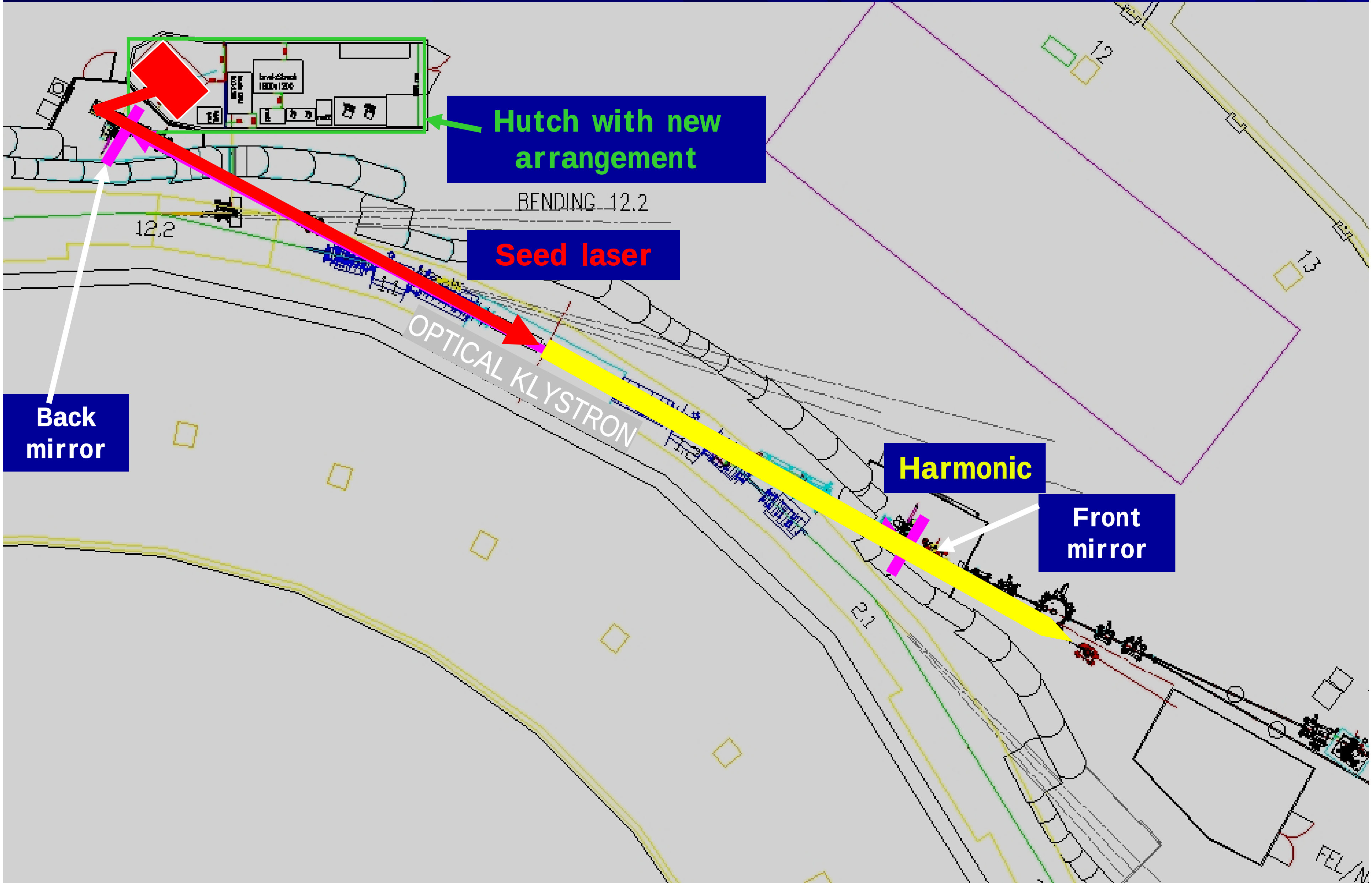
General layout of the Elettra SRFEL

Mauro Trovó



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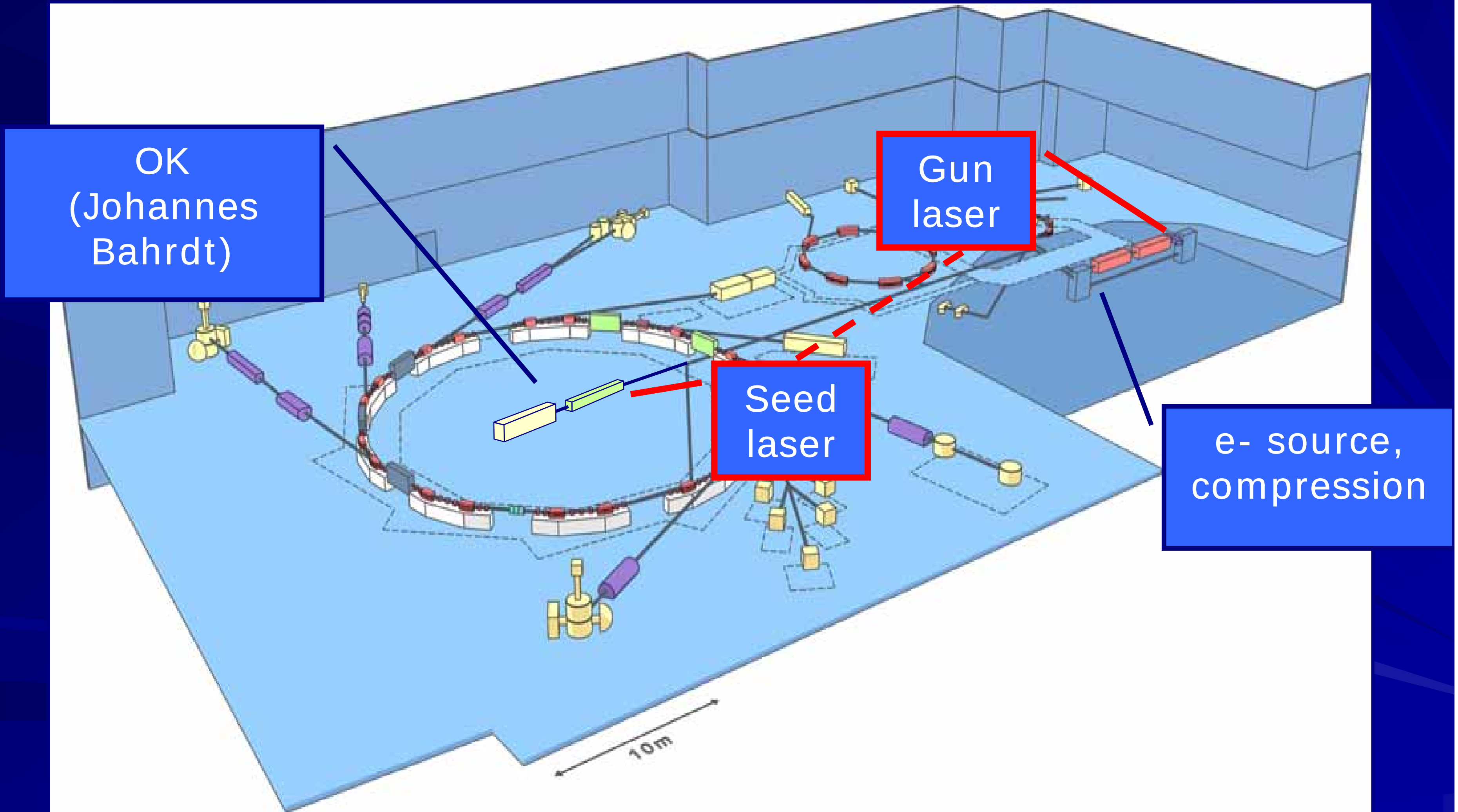
Overall


OK
(Johannes
Bahrdt)
Gun
laser
Seed
laser
e- source,
compression
10m

Modulator Assembly

Magnetic arrays:	ESRF
shimming of structures:	BESSY
similar Carriage as for radiator	BESSY

Parameters:

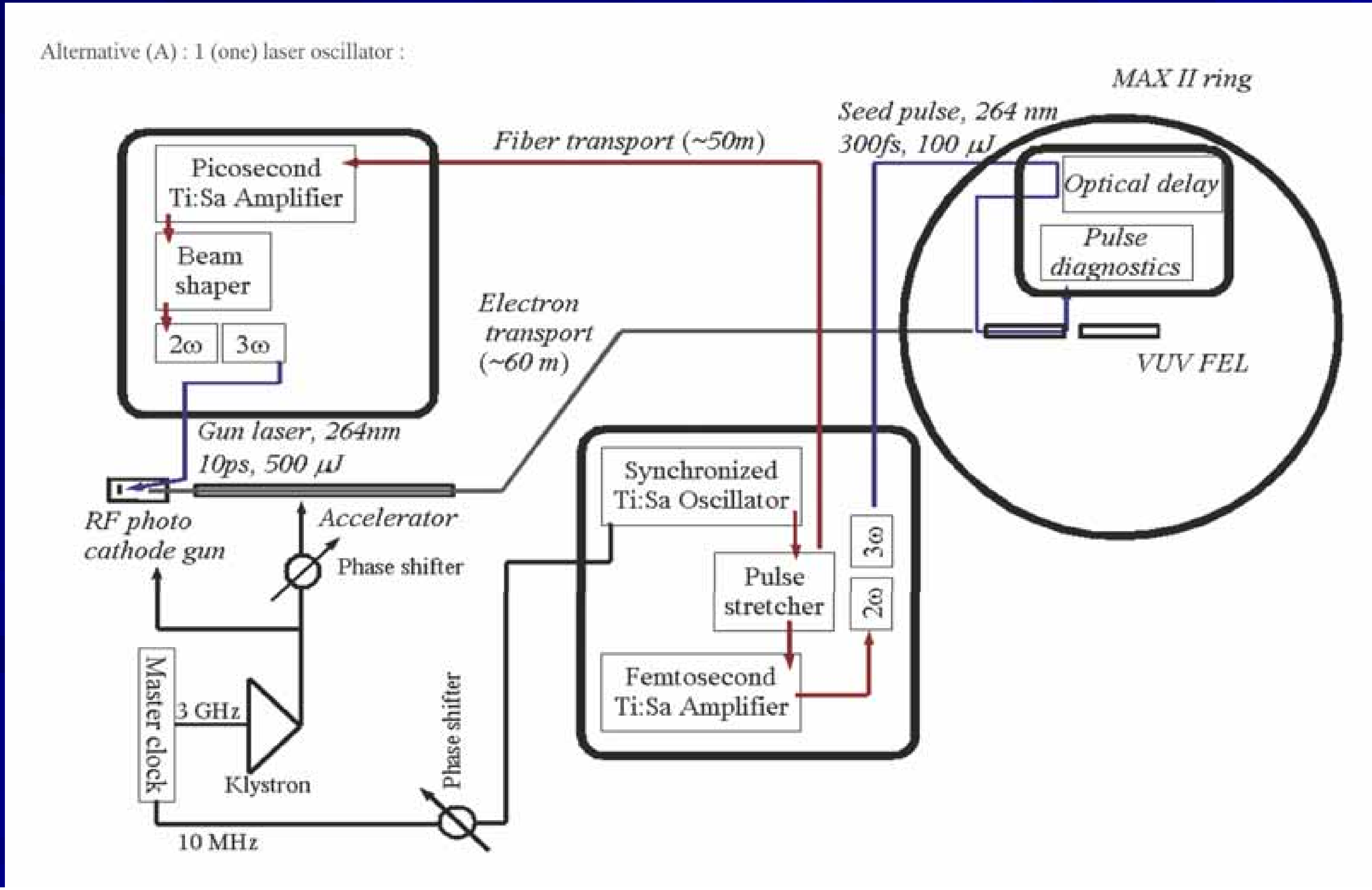
period length:	48mm
number of periods:	30
remanence:	1.15 T
magnetic gap:	9,5mm (compatible with 500MeV)

Project line

- Stage I (+OK)
  Alignment, pointing, overall operation, safety systems, basic e- optics
- Stage II (+Laser)
  Synchronisation, overlap, stability, compression, diagnostics, HG
- Stage III (+Gun II)
  HGHG, full space charge effects

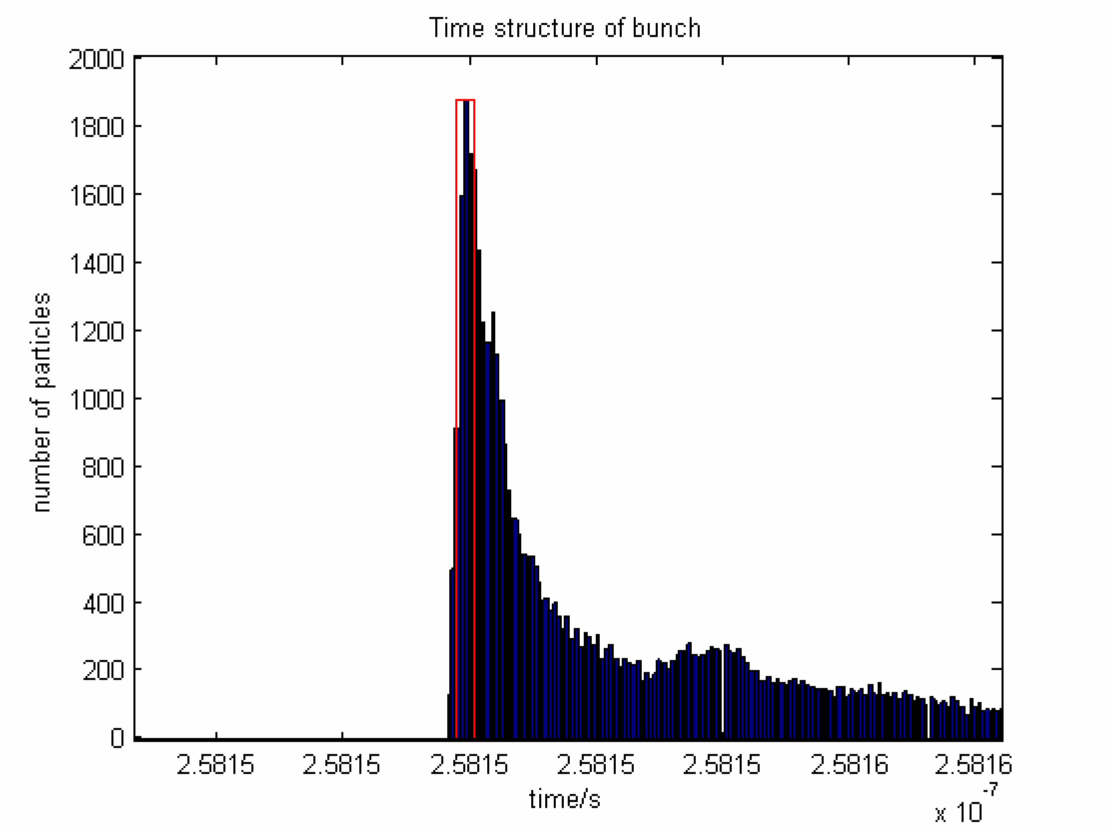
Laser systems (gun + seed)

- Evaluating bids.



Compression simulations (Stage III) by Sara Thorin

- ΔT = 300 fs (Red box)
- I_peak = 250A
- Q = 0.08 nC
- ε_x = 3.3 mm mrad
- ε_y = 2 mm mrad



The boring stuff

- Demands for additional funding (redistribution of leftovers?)
- Budget, spending excel sheet
- Timeplans

IRUVX-FEL

The facility

Intense light beams from the Infrared to the Soft X-rays are the major probe to study the electronic properties of Matter and will involve a very large user community. The development of Free Electron Lasers allows a new, virtually unexplored, regime of coherent light flashing with femto-second pulses. The IRUVX Consortium will join the resources now in construction and planned in Europe into a unique Research Infrastructure, allowing to offer novel and powerful complementary instruments for the microscopic and the dynamical study, as well as an optimal service to users, prioritising the development and location of the specific beam lines.

Material Sciences

Estimated construction cost (M€)	760 M€
First open access foreseen	2006-2015

Website

www.iruvx.eu

Background

A recent technological breakthrough has allowed developing new light sources based on Free Electron Lasers (FELs) in the infrared to soft x-ray wavelength range, flashing with femto-second pulses, large coherence and high brilliance, producing very collimated beams "illuminating" at atomic level the components of materials to observe both their structure and dynamical behaviour.

What's new? Impact foreseen?

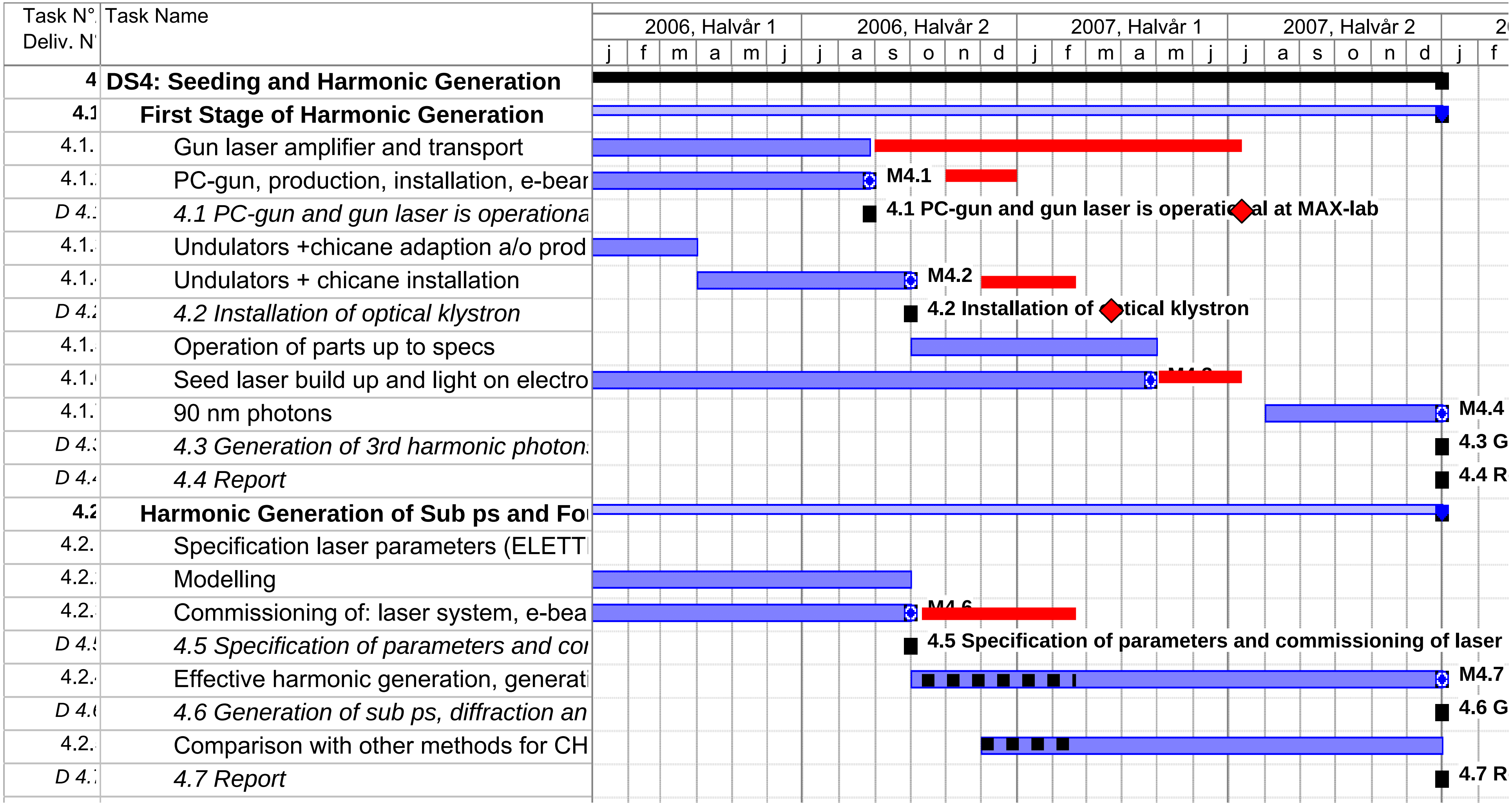
The area is under rapid technical development, with Europe at the forefront. The interaction between matter and electromagnetic radiation in this regime is virtually unexplored. State of the art 3rd generation synchrotron sources will be surpassed in peak intensity by factors of 10^{8}-10^{9}, in average intensity and in their short-time flashing capabilities by 10^{3}-10^{4} down to a few femto-seconds, pushing experimental techniques to new frontiers. The photon beams of Soft-FELs will have completely new qualities compared to those of synchrotrons at photon energies between 10 eV and 1 keV. Europe has the unique chance for consolidating its world leadership in a field of highest relevance.

Scientific challenges and opportunities will open for a wide range of scientific disciplines, ranging from nanosciences, materials and biomaterials sciences, plasma physics, molecular and cluster, femto- and nano- physics and chemistry, various connections to life, environmental, astrophysical and earth sciences and the development of technologies ranging from micro electronics to energy. Some novel emerging synchrotron techniques, like holographic coherent imaging or ultra fast pump-probe studies will greatly benefit from the enhanced beam properties. We can today only imagine some of these opportunities and it is likely that the most important use of soft-FELs have not yet even been thought of.

Timeline and estimated costs

Five facilities, in different and scaled phases of development are involved in the proposal. One in operation (FLASH at DESY, Hamburg), one in construction (FERMI @ Elettra, Trieste), two in advanced technical demonstration and technological development phase (4GLS in Daresbury and BESSY in Berlin) and one in conceptual phase (MaxLab in Lund). Other projects may enter the consortium from The Netherlands, France and Switzerland. FLASH and Elettra are approved for a total cost of 237 M€, as well as the development costs of 4GLS and BESSY for a total of 71 M€.

Total implementation has an estimated cost of ~660 M€, a preparatory cost of ~15% of the construction, and an estimated operation cost of 65-70 M€.



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4 DS4: Seeding and Harmonic Generation
4.1 First Stage of Harmonic Generation
4.1. Gun laser amplifier and transport
4.1. PC-gun, production, installation, e-bear
D 4. 4.1 PC-gun and gun laser is operationa
4.1. Undulators +chicane adaption a/o prod
4.1. Undulators + chicane installation
D 4. 4.2 Installation of optical klystron
4.1. Operation of parts up to specs
4.1. Seed laser build up and light on electro
4.1. 90 nm photons
D 4. 4.3 Generation of 3rd harmonic photon
D 4. 4.4 Report
4.2 Harmonic Generation of Sub ps and Fo
4.2. Specification laser parameters (ELETT
4.2. Modelling
4.2. Commissioning of: laser system, e-bea
D 4. 4.5 Specification of parameters and co
4.2. Effective harmonic generation, generati
D 4. 4.6 Generation of sub ps, diffraction an
4.2. Comparison with other methods for CH
D 4. 4.7 Report
M4.1
4.1 PC-gun and gun laser is operational at MAX-lab
M4.2
4.2 Installation of optical klystron
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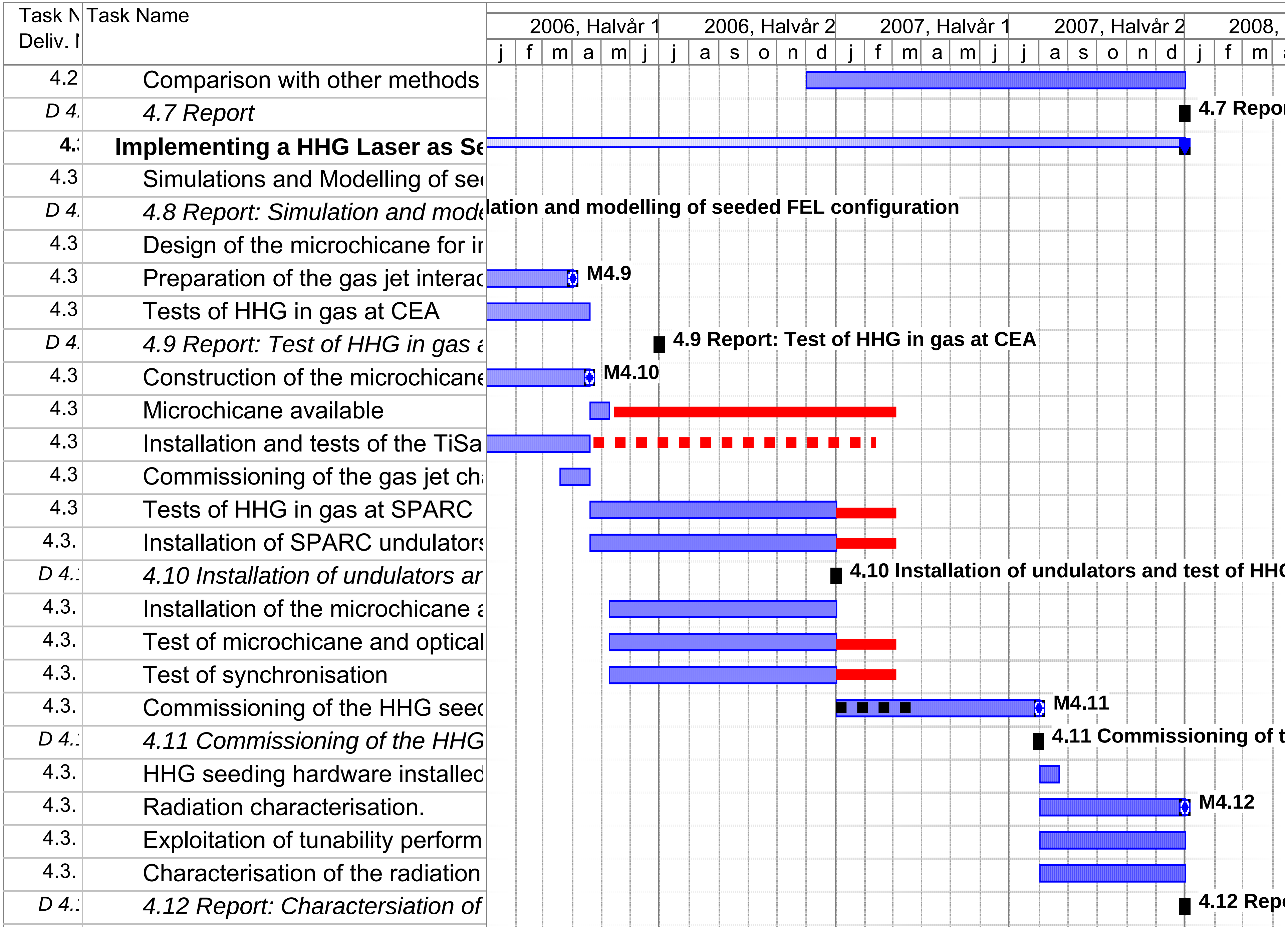
4.3 G
4.4 R
4.5 Specification of parameters and commissioning of laser
M4.7
4.6 G
4.7 R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4.3 Simulations and Modelling of se
D 4. 4.8 Report: Simulation and mode
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4.3 Design of the microchicane for ir
4.3 Preparation of the gas jet interac
M4.9
4.3 Tests of HHG in gas at CEA
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4.9 Report: Test of HHG in gas at CEA
4.3 Construction of the microchicane
M4.10
4.3 Microchicane available
4.3 Installation and tests of the TiSa
4.3 Commissioning of the gas jet ch
4.3 Tests of HHG in gas at SPARC
4.3. Installation of SPARC undulators
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4.3. Test of microchicane and optical
4.3. Test of synchronisation
4.3. Commissioning of the HHG seed
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4.3. HHG seeding hardware installed
4.3. Radiation characterisation.
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4.3. Characterisation of the radiation
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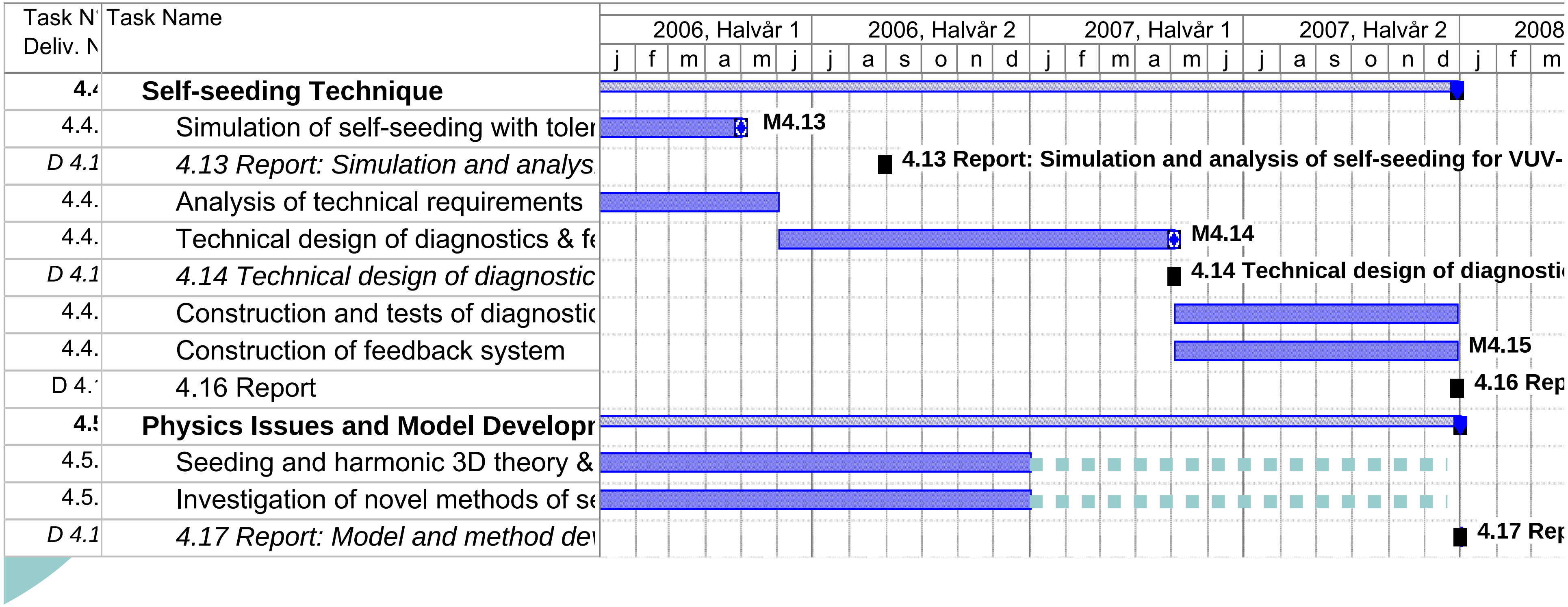

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4.4. Analysis of technical requirements
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4.5 Physics Issues and Model Developm
4.5. Seeding and harmonic 3D theory &
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