FACULTY OF SCIENCE, MATHEMATICS AND COMPUTING SCIENCE

Rienk Jongma

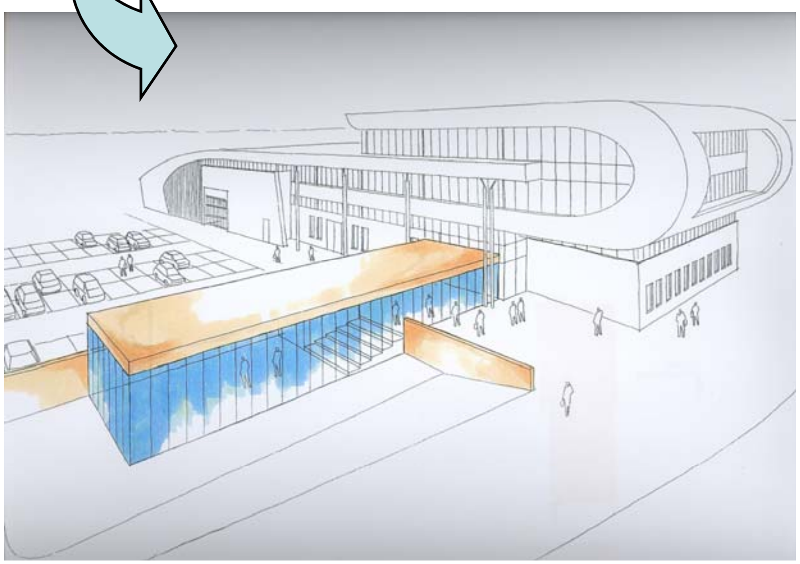
Design of the Nijmegen High-Resolution FIR/THz-FEL

IMM Institute for Molecules and Materials

Radboud University Nijmegen

Nijmegen THz-FEL

- GOALS
  - **spectroscopy / dynamics in solid state materials in high B-fields**
  - **molecular spectroscopy of bio-organic molecules**



45 T in 2012

Design team


Nijmegen team:
Wim van der Zande (PI)
Rienk Jongma (project leader)
André van Roij
Jos Perenboom
Theo Rasing
Lex van der Meer
Peter van der Slot
Christian Piel
Kai Dunkel
ACCEL
Ulf Lehnert
Rudi Wünsch
Peter Michel
Pulsar Physics
Kees van der Geer
Hamburg
Bremen
Hannover
Berlin
Potsdam
Den Haag
Rotterdam
Köln
Deutschland
Germany
Dresden
België
Belgique
Belgium
Mainz
Praha

Special features of the Nijmegen THz-FEL

- **Spectral range** **0.1 - 1.5 mm (0.2 - 3 THz)**

Requirements

a) “Pump-probe” high-power mode

- Bandwidth limited pulses 0.5 - 2% (5 - 80 ps)
- Macro/micropulse power 3 kW / 100 kW

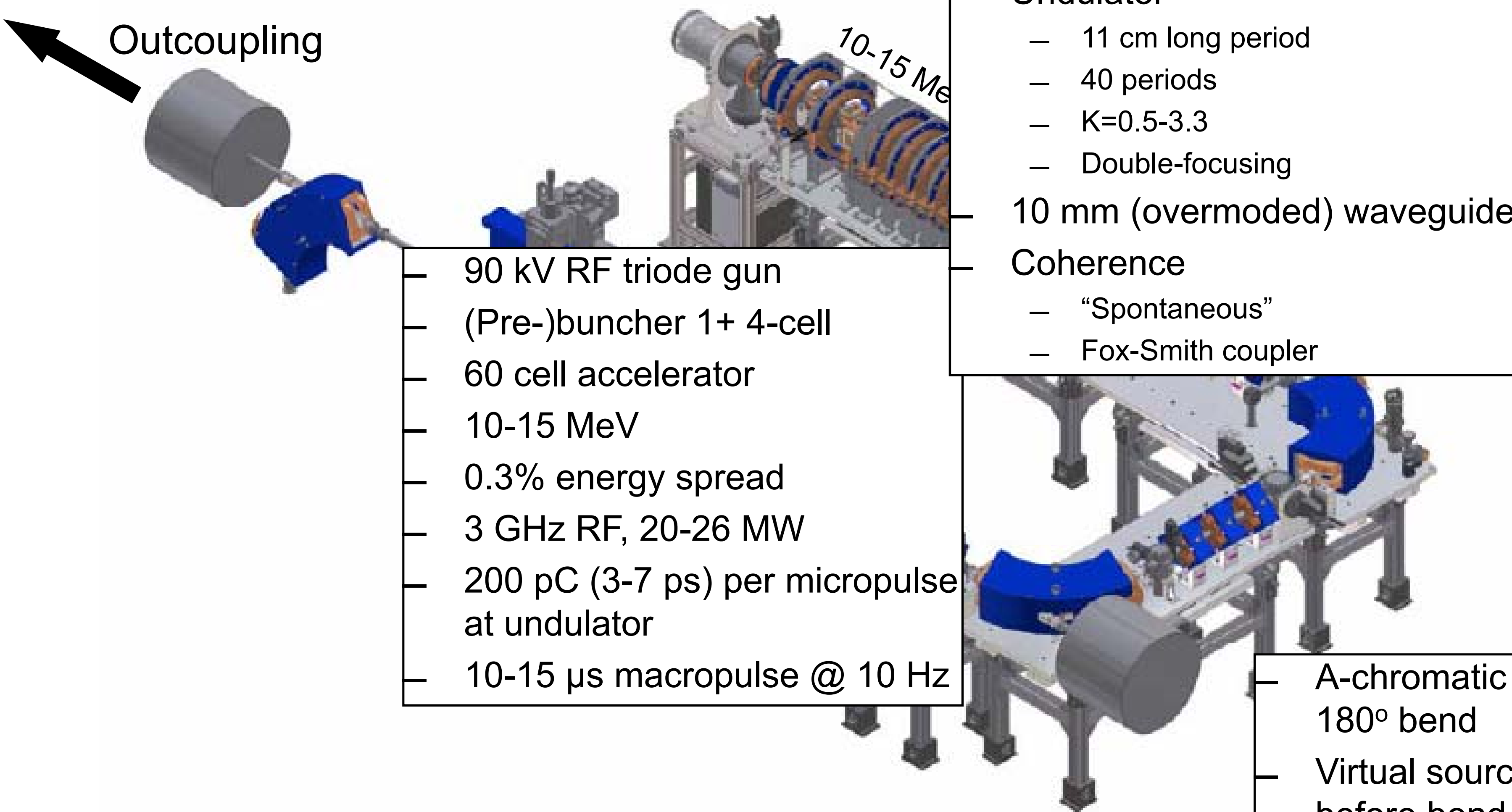
b) Narrow band (long pulse) “spectroscopic” mode

- ***Bandwidth $\Delta\lambda/\lambda$*** ***10^{-6} - 10^{-5}***
- Pulse length ~10 μs
- Power 100 Watt

- Combine pump/probe and narrow band in single instrument?

Note: science case, spectral range and operational mode *differ from FELIX*

Pre-design FEL system

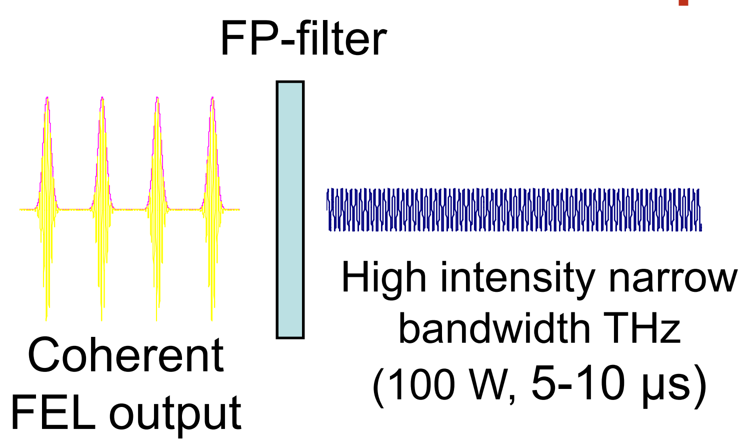


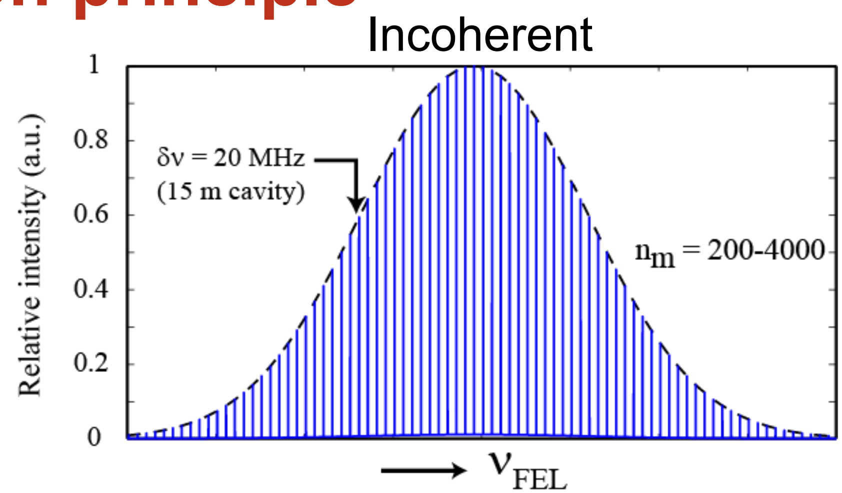
- 7.5 m cavity
- Undulator
  - 11 cm long period
  - 40 periods
  - K=0.5-3.3
  - Double-focusing
- 10 mm (overmoded) waveguide
- Coherence
  - “Spontaneous”
  - Fox-Smith coupler

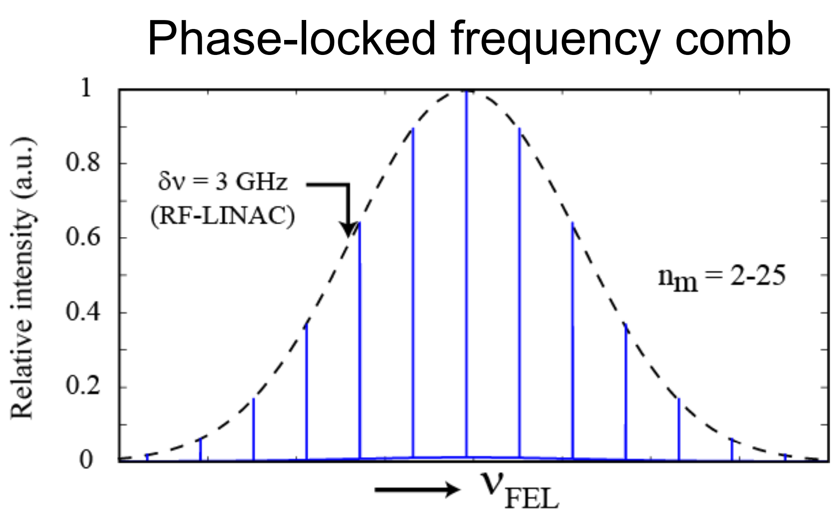
- 90 kV RF triode gun
- (Pre-)buncher 1+ 4-cell
- 60 cell accelerator
- 10-15 MeV
- 0.3% energy spread
- 3 GHz RF, 20-26 MW
- 200 pC (3-7 ps) per micropulse at undulator
- 10-15 μs macropulse @ 10 Hz

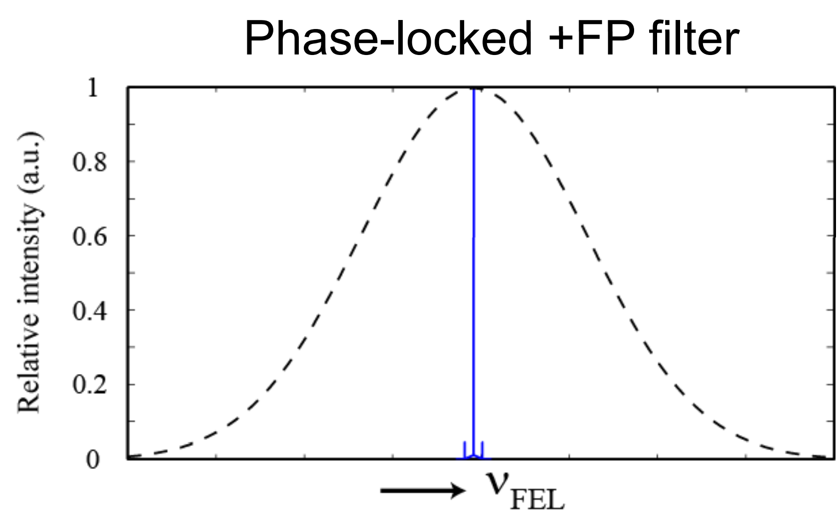
- A-chromatic 180° bend
- Virtual source before bend

Narrow-band operation principle





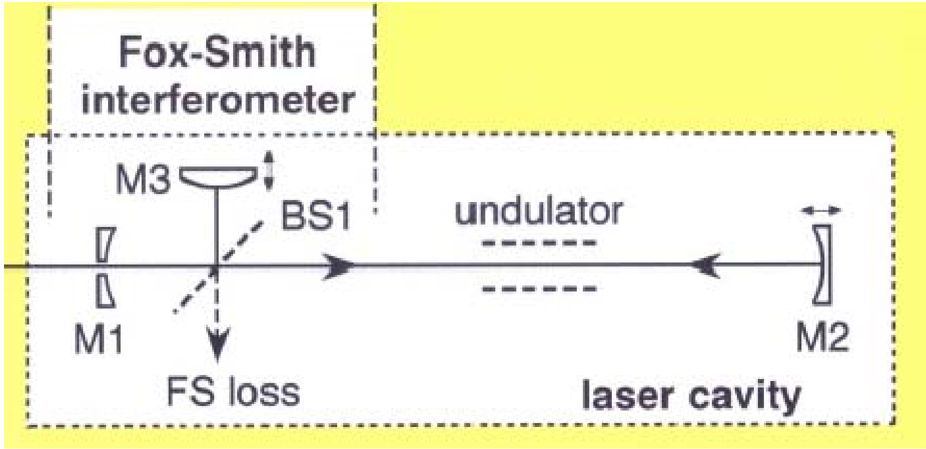




Demonstrated previously: Oepts and Colson *(1990)*, Bakker, Oepts, Van der Meer *et al. (1993),* Oepts, Weits, Van der Meer *et al.* (*1996-1998*), Szarmes, and Madey (*1993*), Israeli Project (2005) and others . .

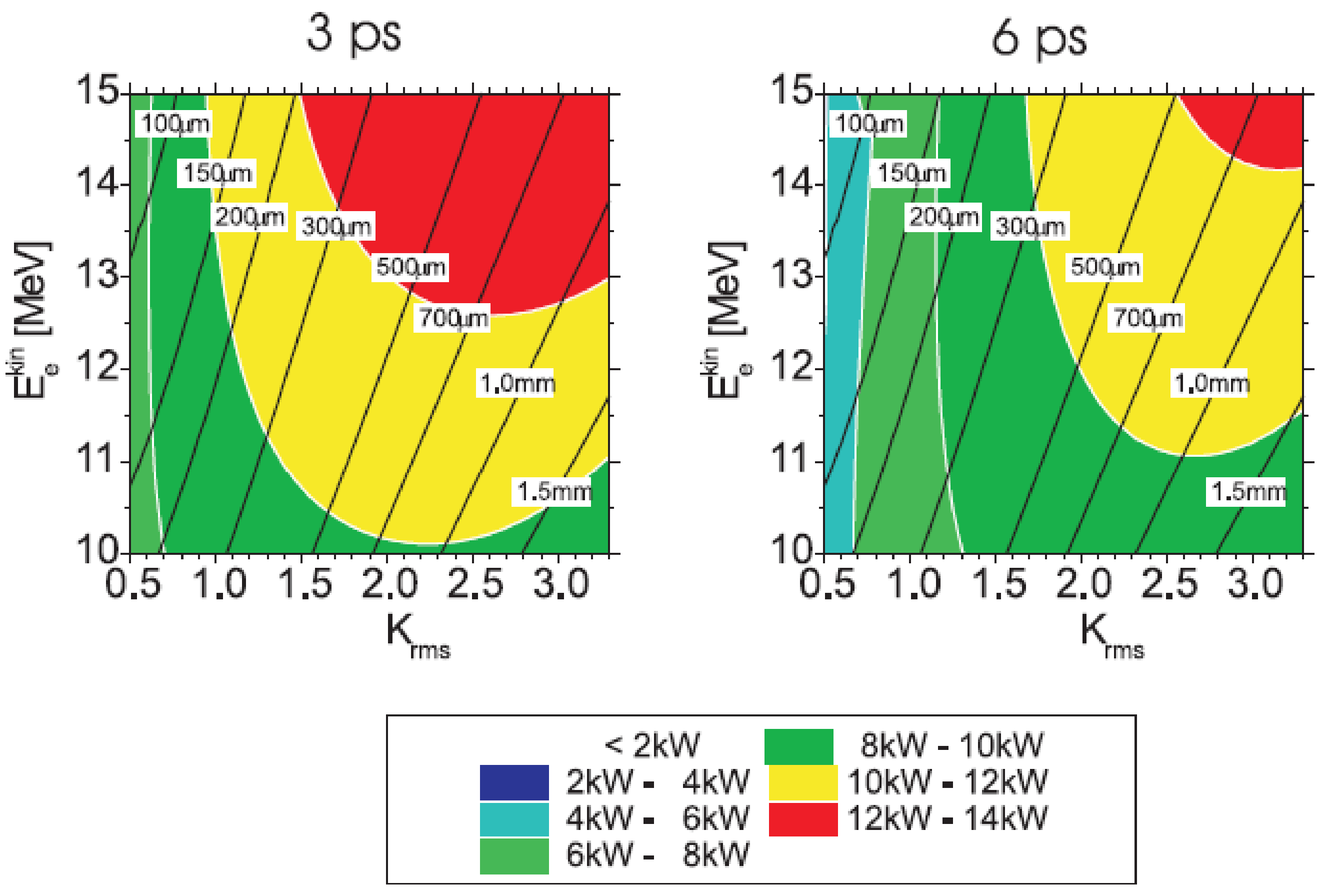
Phase-locked frequency comb

- "Spontaneous" coherence
  - Stable injection of electron pulse in undulator
  - Relatively easy because of ***very high slippage*** (μ_c=5-70 **(!)**)
  - No optics, no continuous tunability (3 GHz steps)
- "Induced" Coherence



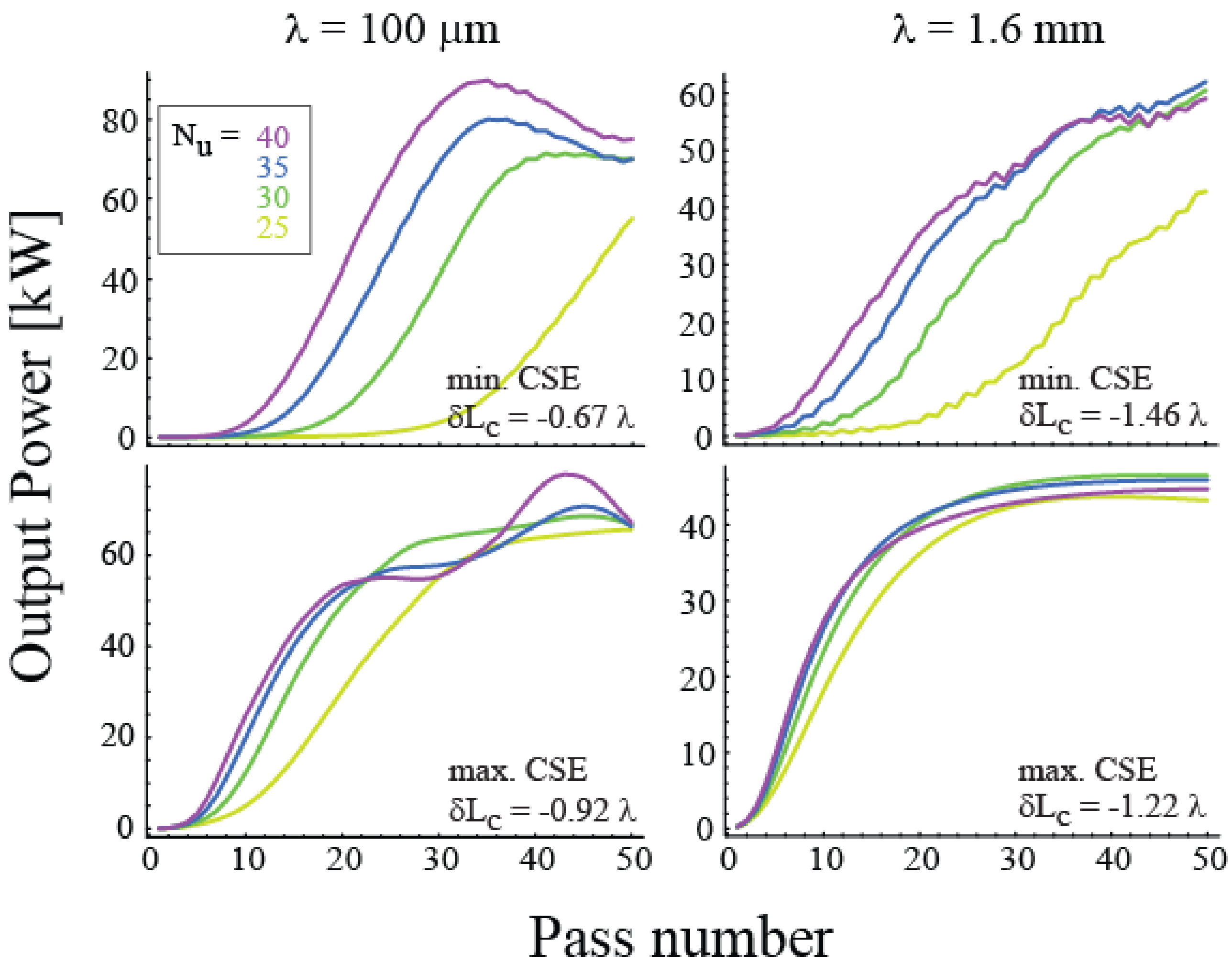
  - Requires longer electron bunch
    (conflicts with spontaneous coherence)
  - Continuous tuning, increased startup time

Saturation power (first principles)



Total losses: 22%, outcoupling: 7%

GPT simulations of start-up behavior



At 1.6 mm single pass mirror-less laser operation may be possible

Conclusions

- Pre-design study yields compact FEL system
  - LINAC system based on proven RF technology, 3 GHz operation gun challenging
  - Elegant electron beam transport system
  - Compact, fully wave-guided cavity
- No show-stoppers for “pump-probe” mode operation
- Narrow-band operation most challenging: *coherence difficult to quantify (project!)*
- First lasing: First Half 2011

Acknowledgements

- National (NL) Programme for Investments in Large Scale Facilities
- Design team Nijmegen THz-FEL
- Fruitful discussions and feedback:
  - George Neil and JLabs FEL-team
  - Todd Smith (Stanford)
  - Jerry Ramian (UCSB)