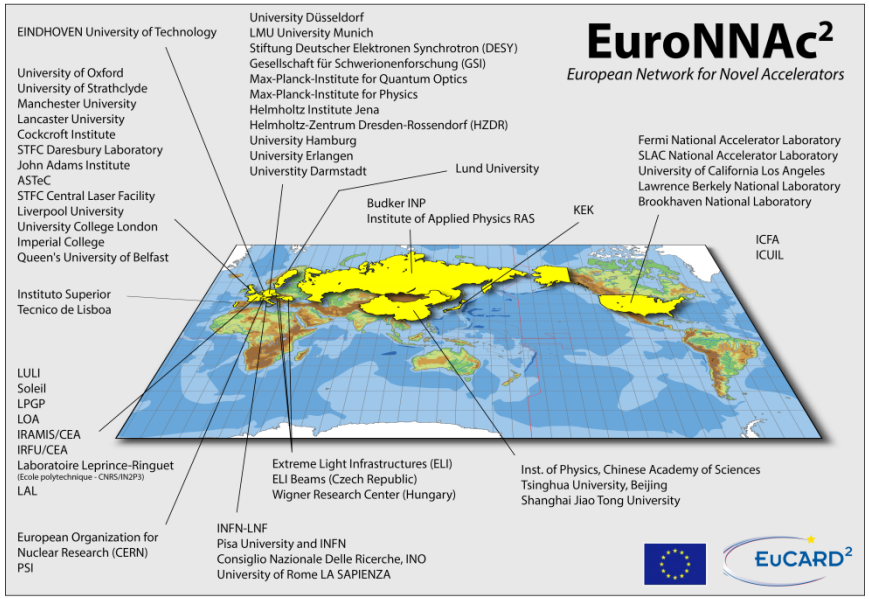
Report from WP7: EuroNNAc² - European Network for Novel Accelerators

EuCARD2 yearly meeting, Malta, 26.04.2016
U. Dorda (DESY) for the steering committee:
R. Assmann (DESY), M. Ferrario (INFN), B. Holzer (CERN), J. Osterhoff (DESY)
A. Seryi (JAI), A. Specka (ecole polytechnique)

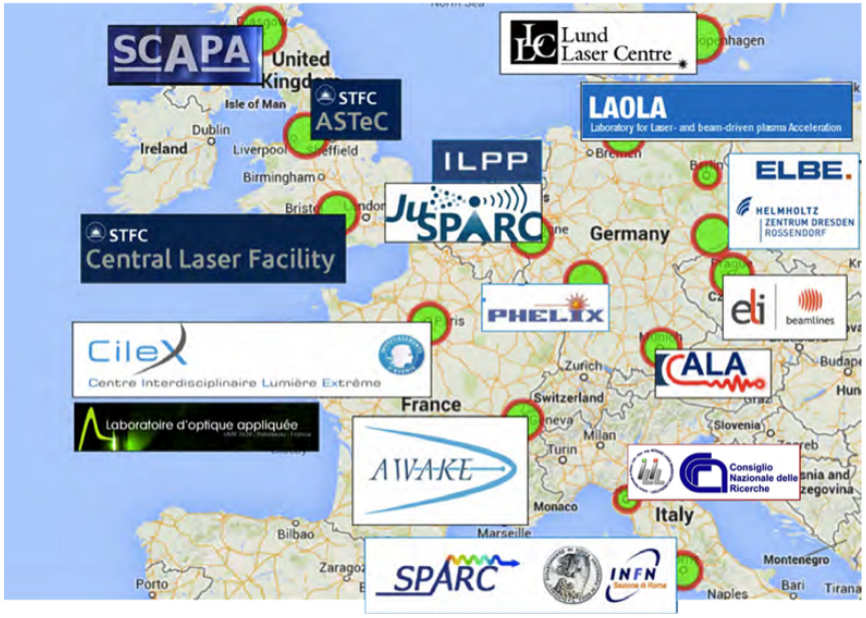
EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

WP7 - Intro

- Activity type: Coordinating
- Coordinated by CERN, Ecole polytechnique and DESY
- Managed by a steering committee: R. Assmann (DESY), M. Ferrario (INFN), B. Holzer (CERN), J. Osterhoff (DESY), A. Seryi (JAI), A. Specka (ecole polytechnique).



Institutes being members of the EuroNNAc network

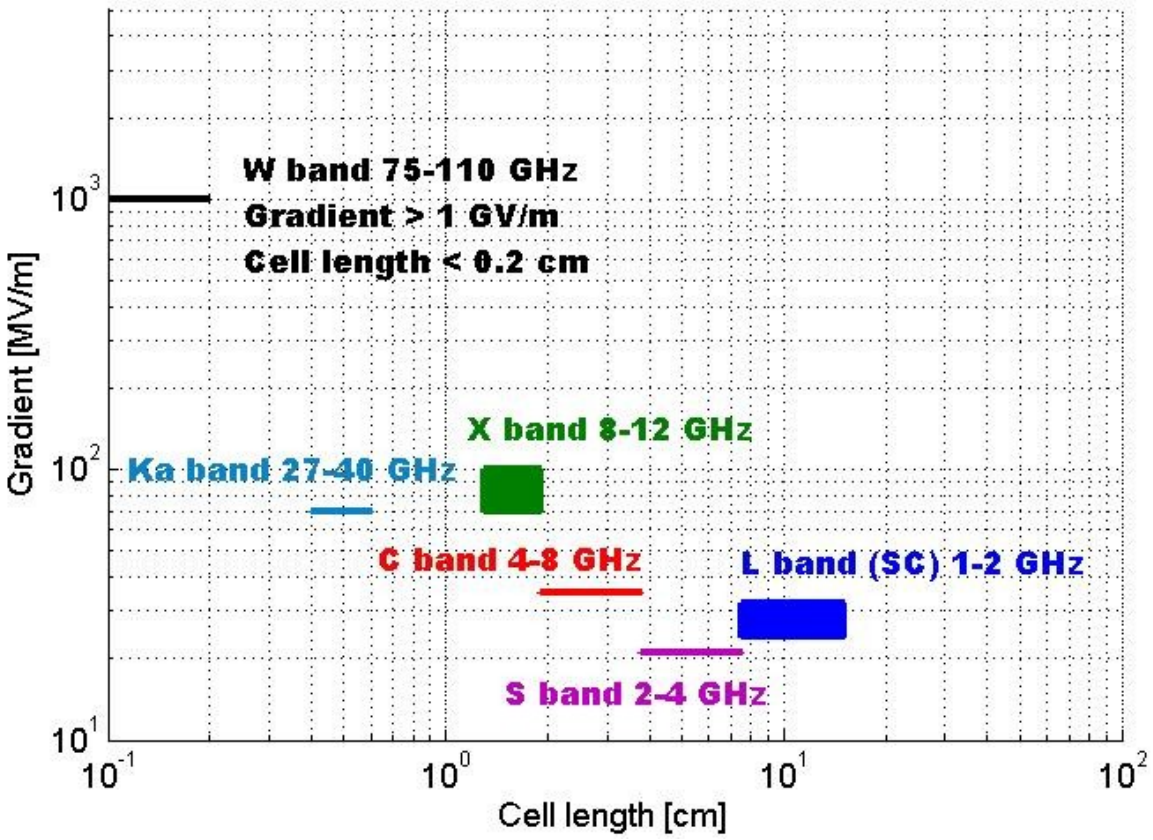


European accelerator research facilities represented in EuroNNAc

WP7 - Mission

- The European Network for Novel Accelerators EuroNNAc2 aims at federating the significant European effort in plasma-based accelerators in order to prepare a roadmap for an efficient use of this novel technology in full-scale accelerators.

Towards higher frequencies



- Correlation
  - RF frequency
  - gradient
  - cell length
- Moving to higher frequencies the accelerators are more compact
- W-band is attractive but not trivial to achieve because…

2 directions

High Gradients (1-100 GV/m) → High Frequencies (> 100 GHz) → Small Dimensions (< 1 mm)

- No klystrons for high frequencies! → Use particle bunches or laser pulses as drivers.
- Material limitations → dielectric materials, plasma cavities, …

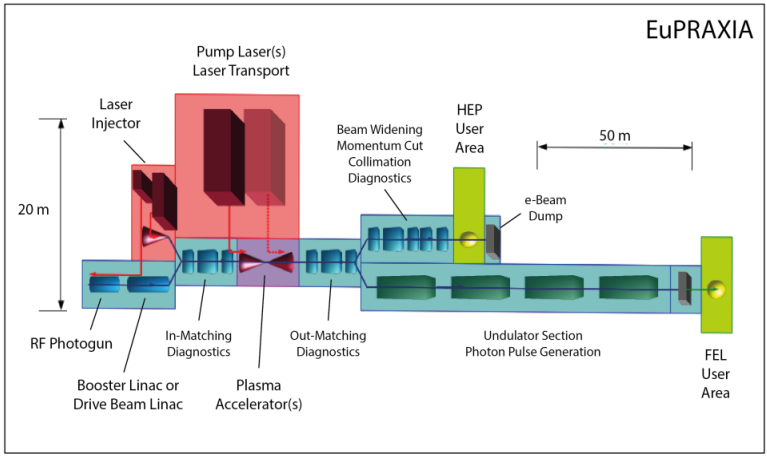
Two main directions:

1 **Microstructure Accelerator**
Laser- or beam driven
Vacuum accelerators
'Conventional' field design

2 **Plasma Accelerator**
Laser- or beam driven
Dynamic Plasma Structure
Plasma field calculations

EuPRAXIA

- Design study for a “Compact European plasma accelerator with superior beam quality”
- EU-Design Study (Horizon 2020: Infradev-1-2014-1 RIA)
- 16 beneficiaries from 5 EU member states plus 18 associated partners
- http://www.eupraxia-project.eu/
- Started: 01.11.2015



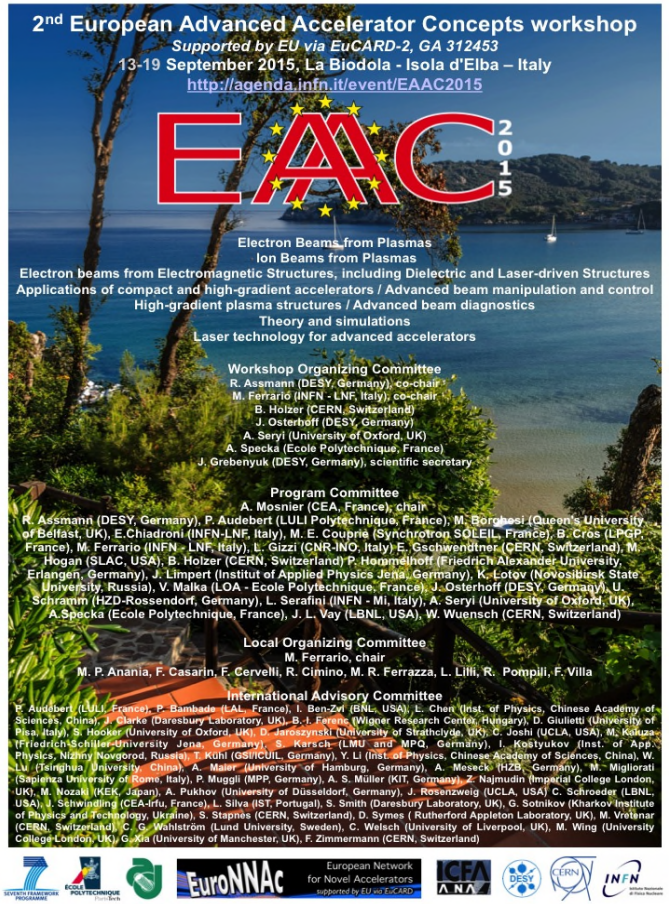
→ See dedicated presentation by R. Assmann this morning

Milestones and Deliverables

Y1	MS58	EuroNNAc2 2013 workshop	7	M12	DONE	M
Y2	MS59	EuroNNAc2 2014 workshop	7	M24	DONE	M
	7.1	Interim EuroNNAc2 report	7	M24	DONE	D
Y3	MS60	EuroNNAc2 2015 workshop	7	M36	DONE	M
Y4	MS61	EuroNNAc2 2016 workshop	7	M48		M
	7.2	Final EuroNNAc2 report - a European roadmap	7	M46		D

2nd European Advanced Accelerator Concepts Workshop

- 13-19 Sept. 2015, Elba
- https://agenda.infn.it/conferenceDisplay.py?ovw=True&confId=8146
- Proceedings
  - 100 submitted papers
  - All pre-prints online available
  - Will be published very soon as special topic issue in NIM-A
- Chair WS: M. Ferrario, R. Assmann
- Chair PC: A. Mosnier
- Organization committee: B. Holzer, J. Osterhoff, A. Seryi, A. Specka, J. Grebenyuk
- 45 student grants



EAAC statistics

- 258 registered participants
  - 218 male (84%), 40 female (16%)
  - 45 sponsored students.
- Participants from 23 countries in 4 continents (11 EU member states):
  - EU member states: 188
  - Other Europe + Russia + Israel: 28
  - US: 30
  - Asia: 11
  - Australia: 1
- Working Groups + Summaries: 7
  - Invited Talks: 30
  - WG Talks: 138
  - Posters: 76

EAAC working groups

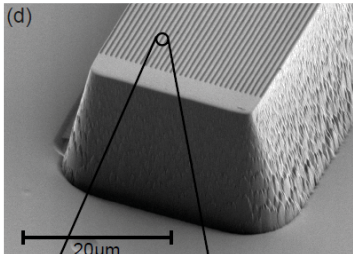
- WG1 - Electron beams from plasmas
- WG2 - Ion beams from plasmas
- WG3 - Electron beams from electromagnetic structures, including dielectric and laser-driven structures
- WG4 - Application of compact and high-gradient accelerators/Advanced beam manipulation and control
- WG5 - High-gradient plasma structures/Advanced beam diagnostics
- WG6 - Theory and simulations
- WG7 - Laser technology for advanced accelerators

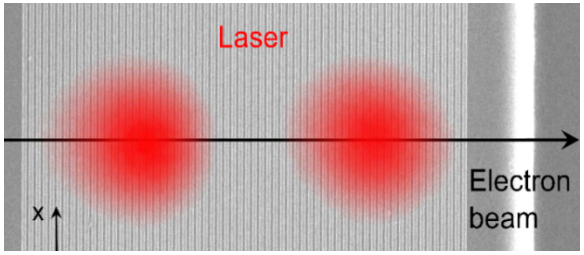
High gradients metallic RF accelerators

- Already well developed technique on the move towards applications and users
- Well defined lab-directed programs – no novel accelerator network needed here but still represented at EAAC'15, e.g.
  - CLIC at CERN, SLAC, … are pursuing X-band for ≤ 100 MeV/m
  - 100GHz copper travelling wave structures!
  - W. Wuensch "Dynamics of Metal Surfaces Under High Fields", 100 MV/m performances at very low breakdown rates
  - E.g: Radiabeam: Carbon NanoTube Cathodes inside RF Environment

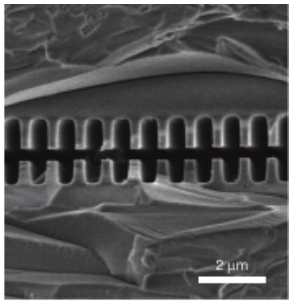
Dielectric laser acceleration

- Acceleration via the excitation of near-field modes at nanograting
- **Up to 3 GeV/m achievable gradient** **(Quartz damage threshold 5GV/m)**
- Currently mainly energy modulation experiments
- Achieved so **far keV energy gains** (but MHz rep-rates)**.**
- **Two stage acceleration proven**
- Future structures will include the gun, sub-micron scale beam position monitors, focusing and tapering to prevent dephasing / slippage.
- Variety of structures, crucial: efficient coupling of the laser
- "Accelerator on a Chip" grant from Moore foundation for work by/at Stanford, SLAC, University Erlangen, DESY, University Hamburg, PSI, EPFL, University Darmstadt, CST, e.g EAAC talk by J. England (SLAC)





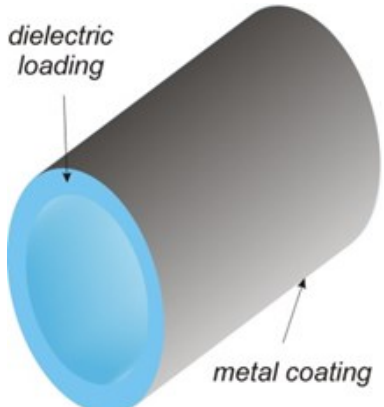
P. Hommelhoff, EAAC'15



E. Peralta , Nature 503 (2013)

THz laser driven dielectric structures

- TM01- mode, Phase-velocity matched to electron velocity by dielectric
  - Increased frequency should imply higher break down fields
  - Reduced pulse energy to achieve same electric field in the cavity -> higher rep-rate
  - High-gradient – compact & short bunches
- THz Sources based on optical rectification
- So far experimentally proven: keV Energy-gain, gradients up to 1 GeV/m possible
- E.g. AXSIS project (ERC synergy grant) at DESY/University Hamburg for THz laser-driven accelerator with atto-second science (included inverse Compton scattering for X-ray generation), see EAAC talk by F .Kaertner (DESY)



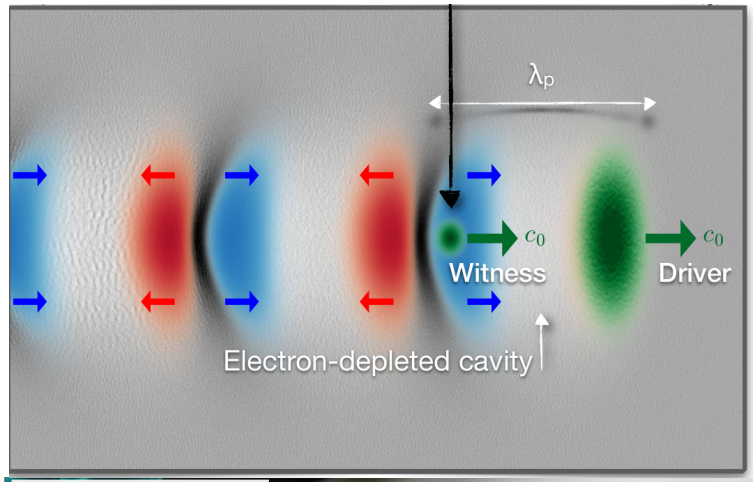
Beam driven dielectric structures

$$\text{Transformer ratio} = \frac{\text{Voltage gain of witness beam}}{\text{Voltage loss of drive beam}}$$

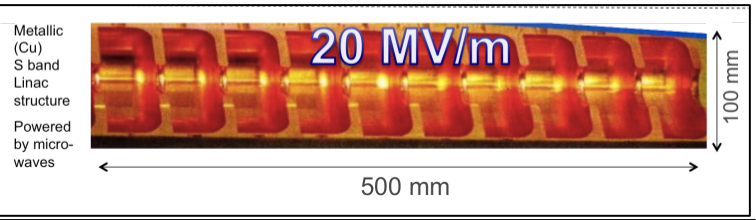
- ‘normally’ limited to TR<2, tricks possible to go highers
- E.g. Argonne Wakefield Accelerator Facility (AWA) : 100GHz rectangular dielectric wakefield structure
- Alternatively: Use structures as “dielectric wakefield shapers” to create a triangular shaped longitudinal distribution

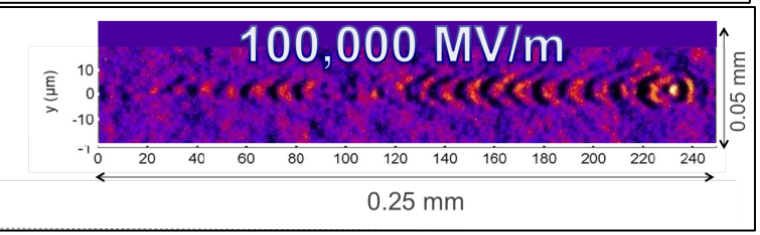
e^- - plasma acceleration

- Particles: electrons & positrons
- Method: Driven by lasers, e-beams or p-beams
- Injection: internal vs. external
- Multi-GeV beams have been achieved
  - → applications around the corner?!
- Development of codes (GPU, super-computers,)…
- Crucial: Improvement of plasma diagnostic.
- Many facilities active or about to start

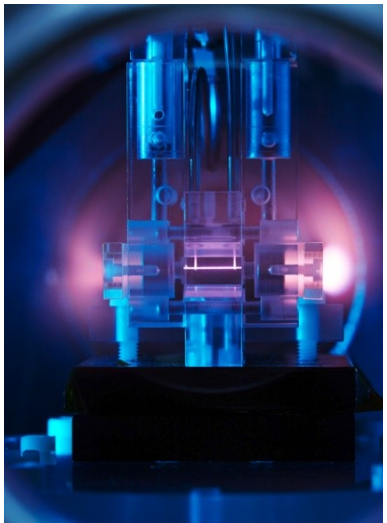


Figures courtesy group J. Osterhoff





Schwab et. al, Phys lett.103



Beam driven e^- - acceleration

- SLAC-FACET:
  - 20GeV electron driver and witness beam
  - Energy doubled in single beam experiment, 2GeV gain for dual beam
  - Stop this year, 2018: FACET II
- ATF: resonant beam driven (60MeV)
- DESY-Zeuthen: SMI tests
- FlashForward
  - Gev electron beam driver,

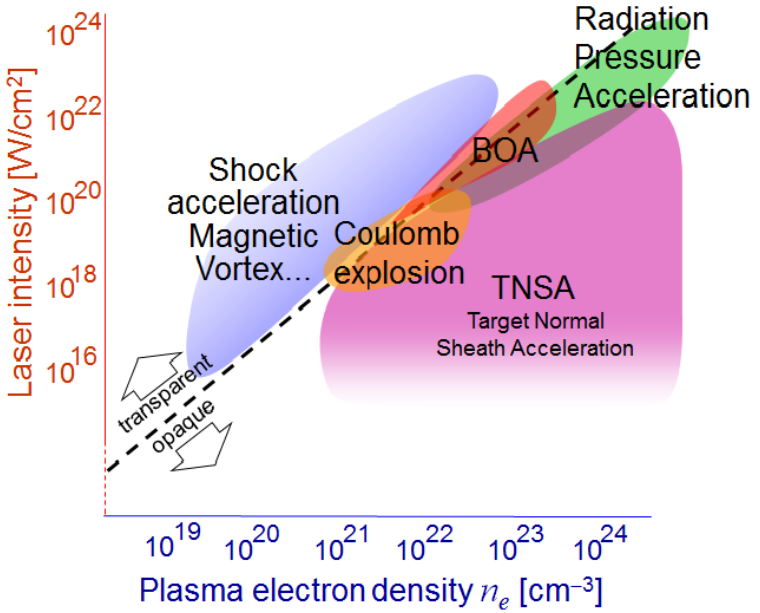
- Proton beam driven (400GeV): AWAKE
  - Drives wakefields over much longer plasma length, only 1 plasma stage needed
  - SMI needed to micro bunch the beam to drive wakefield
  - First tests this year
  - Initial: 10m long plasma chamber

Laser driven e^- acceleration

- LBNL, MPQ, IC, Sparc, Paris, DESY, ...
  - Max energy: 4 GeV
  - Staging demonstrated
  - X-ray generation
- Race for first plasma-based FEL still open
- From acceleration to accelerators:
  - Lower plasma density
  - External injection?
  - Better control of the laser
  - Density ramping
  - Beam loading
- More realistic simulations
  - Tuning parameter for internal injection/ external injection/ extraction from plasma to preserve phase-space
- Target: Gas jets, discharge chambers incl variable length gas targets, ...

Ion plasma acceleration

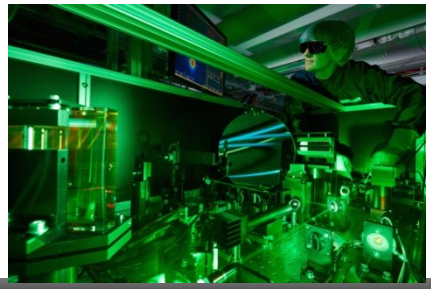
- Various different acceleration regimes
- Achieved:
  - 60-70 MeV on ~ ps systems (NOVA PW, Trident)
  - 30-40 MeV on fs systems (GEMINI, PULSAR, J-KAREN)
- Excellent laser-contrast required
- Targets: sheets (+carbon nano tube layer), cluster targets, structured snow targets, …



U. Schramm, EAAC'15

- First laser driven beam lines under development:
  - E.g. Light experiment at GSI working also on beam transport with pulsed solenoids
  - E.g.: EliMed: to demonstrate that laser accelerated high energy ion beams can be potentially used for multidisciplinary applications, including the medical one.
- → Do not only try to reproduce conventional accelerators but think of applications that may need e.g. large energy spread!

Lasers



- Dielectrics: “comparably low power”
  - In THz still not yet really what needed
- Many new high power lasers coming online
  - two 1PW lasers in Dresden
  - 5PW at CILEX, Saclay
  - .....
- Stability of lasers heavily under work (e.g. contrast)
  - E.g. integration into accelerator control system and feedback loops
- Repetition rate currently still low, increasing efforts to improve
- Fiber lasers
  - Coherent combination

International competition

- Examples:
  - ImPACT Programm in Japanese for the development of a compact plasma-based X-FEL
  - American efforts like SLAC (FACET) & Berkely
  - Bi-yearly AAC has long tradition

→ Significant efforts in Europe but exchange/networking platform needed → EuroNNAc

Conclusion/summary

- Networking place to coordinate & exchange
  - EuPRAXIA started
  - EAAC established as one of the central conferences in this field
    - Plasma: progress towards usability
    - Dielectric accelerators are the newcomers
- The race to the first plasma FEL is still open but (I guess) soon to be finished
- Progress in laser technology keeps advancing the field