WEPAB378 Near-Infrared Laser System for Dielectric Laser Acceleration Experiments at SINBAD

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

IPAC21

DESY.

DLA experiments @ SINBAD (DESY)

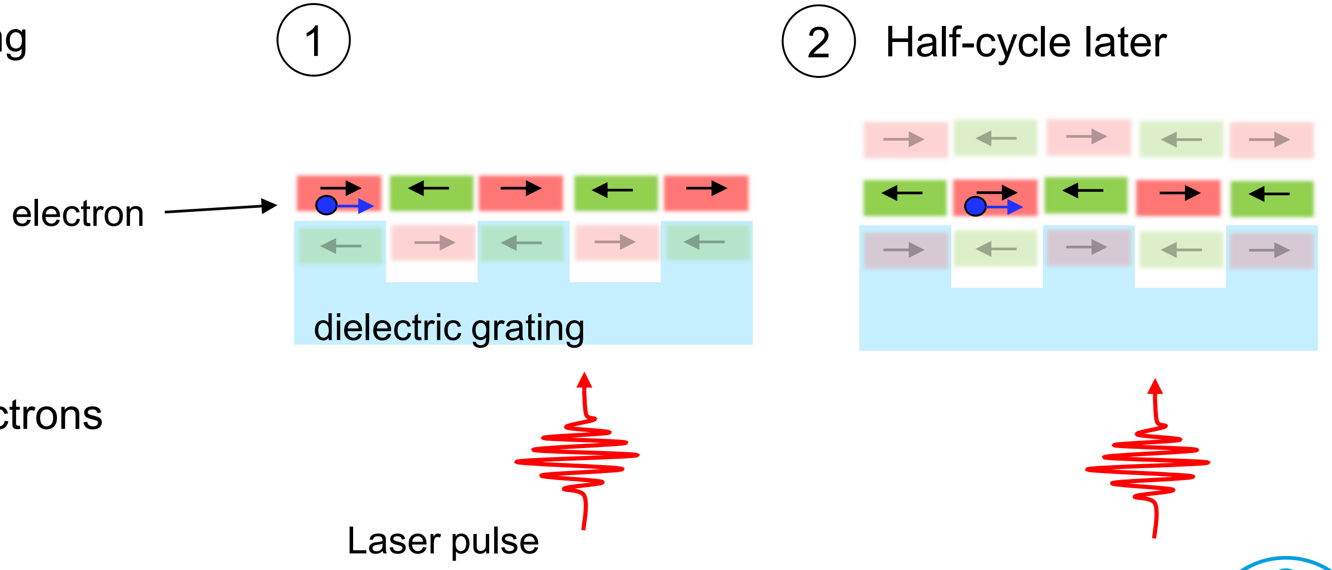
- SINBAD: **Short Innovative Bunches and Accelerators at DESY**
  → dedicated facility for Accelerator Research & Development

- ARES (Accelerator Research Experiment at SINBAD)
  B. Marchetti et al.,J. Phys.: Conf. Ser. 1596, p. 012036 (2020)

- DESY is part of the international **ACHIP** (Accelerator on a chip) collaboration, investigating **Dielectric Laser Acceleration (DLA)**

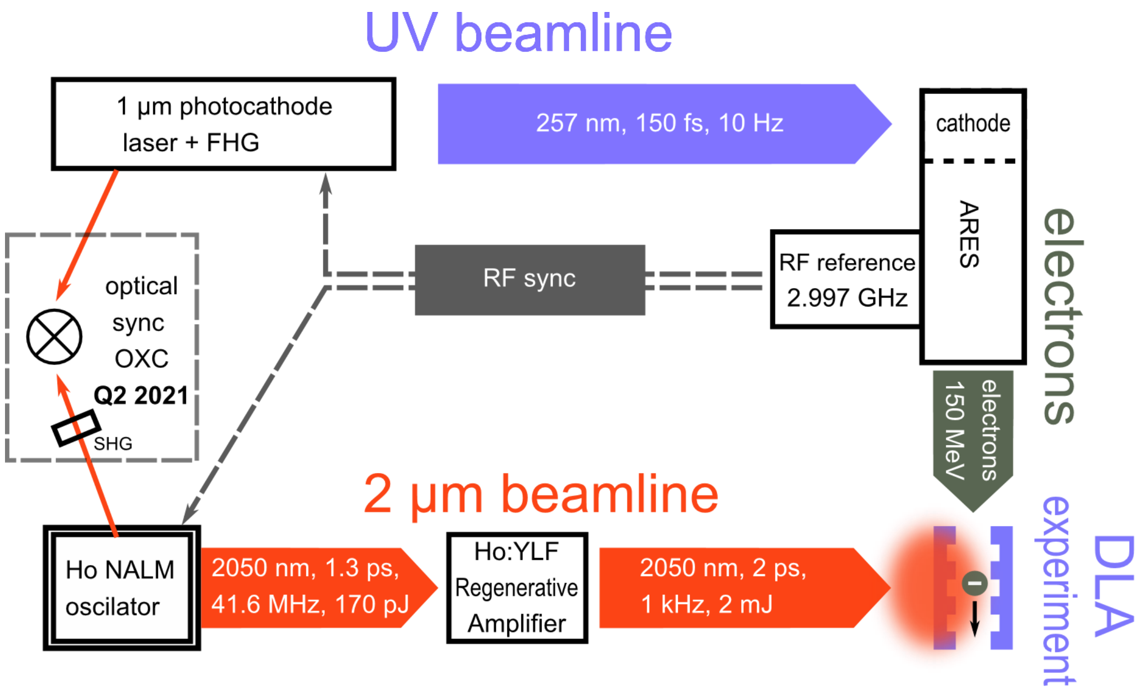
- At SINBAD, laser acceleration on relativistic electrons
- **We here report on the NIR laser system**

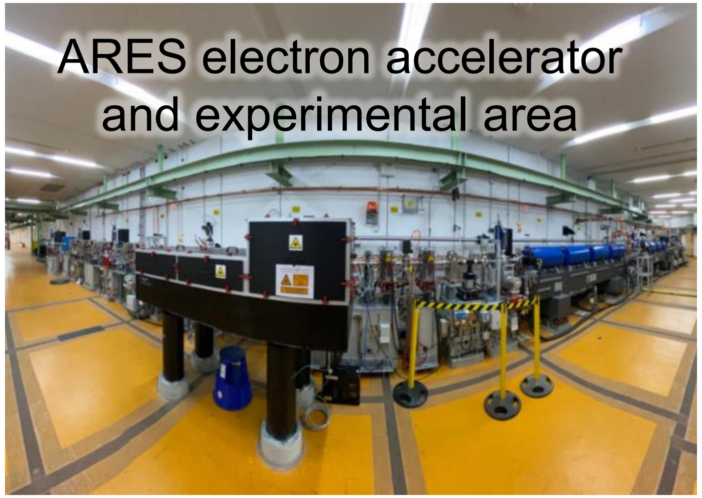
Electron acceleration on a DLA structure



J. Breuer et al., PRL, 111, 134803 (2013).
E. A. Peralta et al., Nature, 503, 91 (2013).

ACHIP experiment @ SINBAD





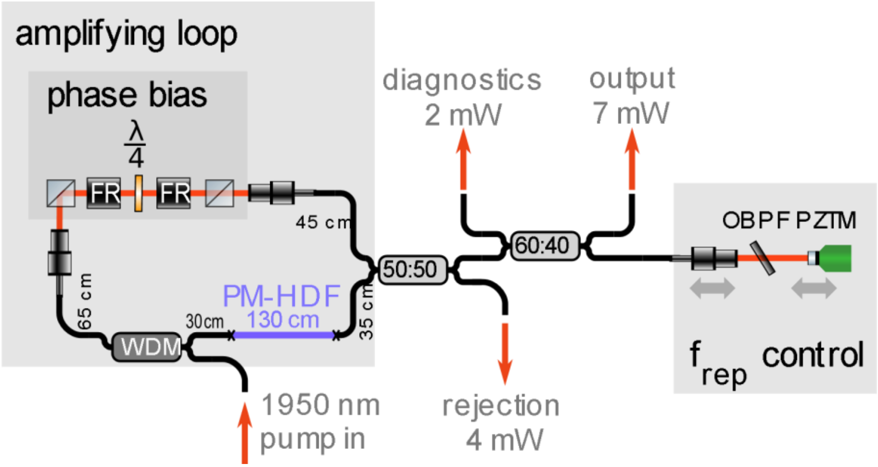
- Two laser systems used: UV – Photoinjector + **2 µm IR laser for DLA experiments**

- **Why operating at 2 µm?**
  - High damage threshold of dielectric materials
  - Less distortion on electron bunch energy distribution (compared e.g. to 800 nm)
  - Dielectric structures of suitable size can be produced

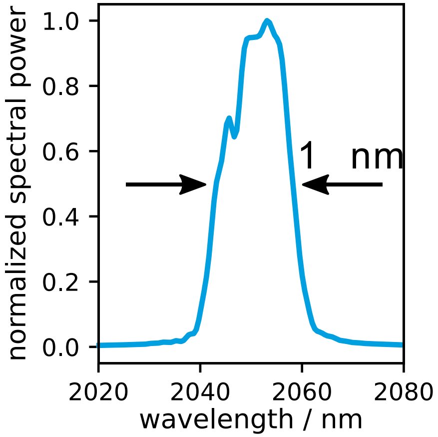
- **Challenges:**
  - Realize Laser system
  - Beam delivery
  - Synchronization + Timing

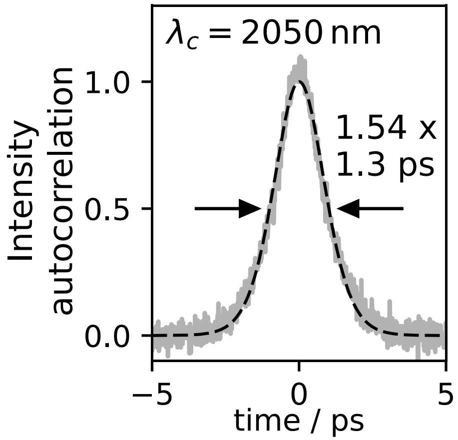
2050 nm Ho:fiber laser oscillator

- Constructed in-house for DLA-experiments
  - Holmium-doped gain fiber (emission at 2050 nm)
  - Synchronizable (control of repetition rate)
  - Nonlinar Amplifying Loop Mirror (NALM) used for mode-locking
- Features:
  - Long term stable
  - Optimized for seeding Ho:YLF amplifer



Repetition rate	41.6 MHz
Pulse energy	170 pJ
Pulse duration	1.3 ps
Wavelength	2050 nm
Spectral width	15 nm





Ho:YLF Regenerative Amplifier at 2050 nm

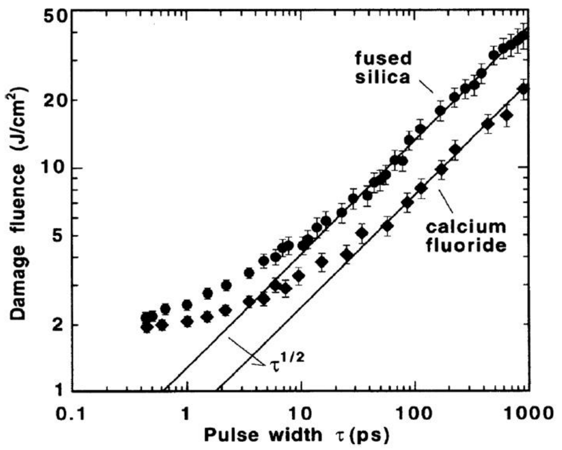
- Regenerative amplifier with subsequent single-stage amplifier → **amplify pulses to mJ level**

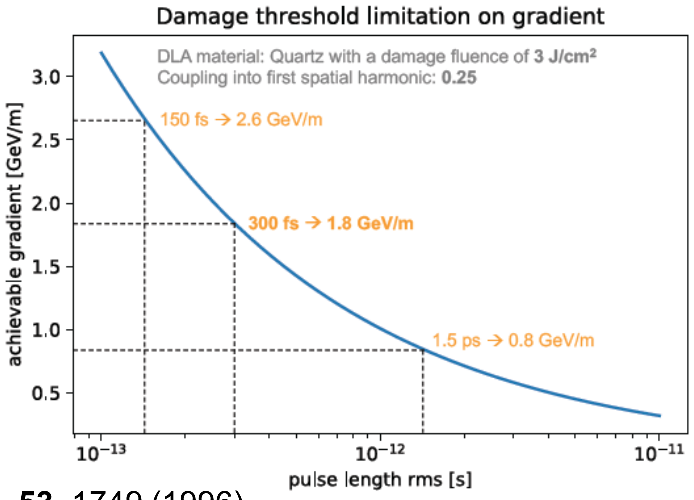
  P. Kroetz et al., Appl. Phys. B, 123(2017)
- Intra-cavity **gain shaping** with etalon reduces the effect of gain-narrowing

  K. Murari et al.,OL 41, 1114 (2016)
- Allows ~ 2 ps pulses → high peak fluence on DLA structures

	Original	Modified
E_p	2 mJ	2 mJ
f_{rep}	1	1
τ_p	3.6 ps	2.2 ps
τ_{TL}	2.2 ps	1.25 ps

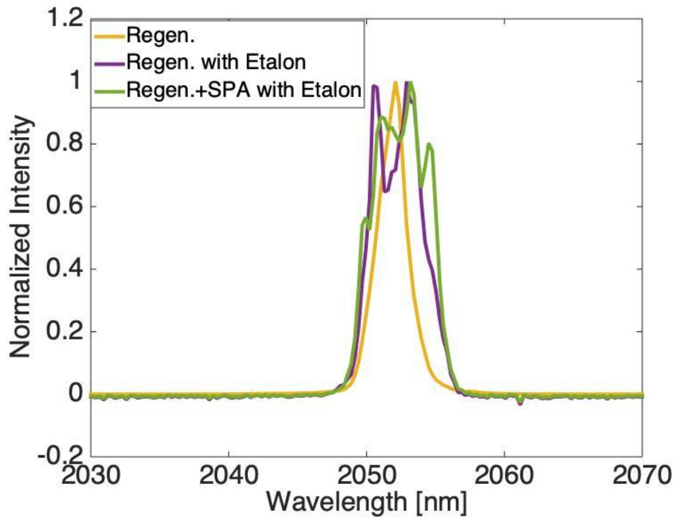
Limitation for field gradient: damage threshold of DLA



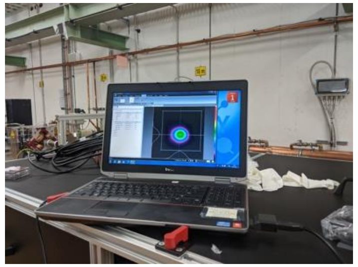


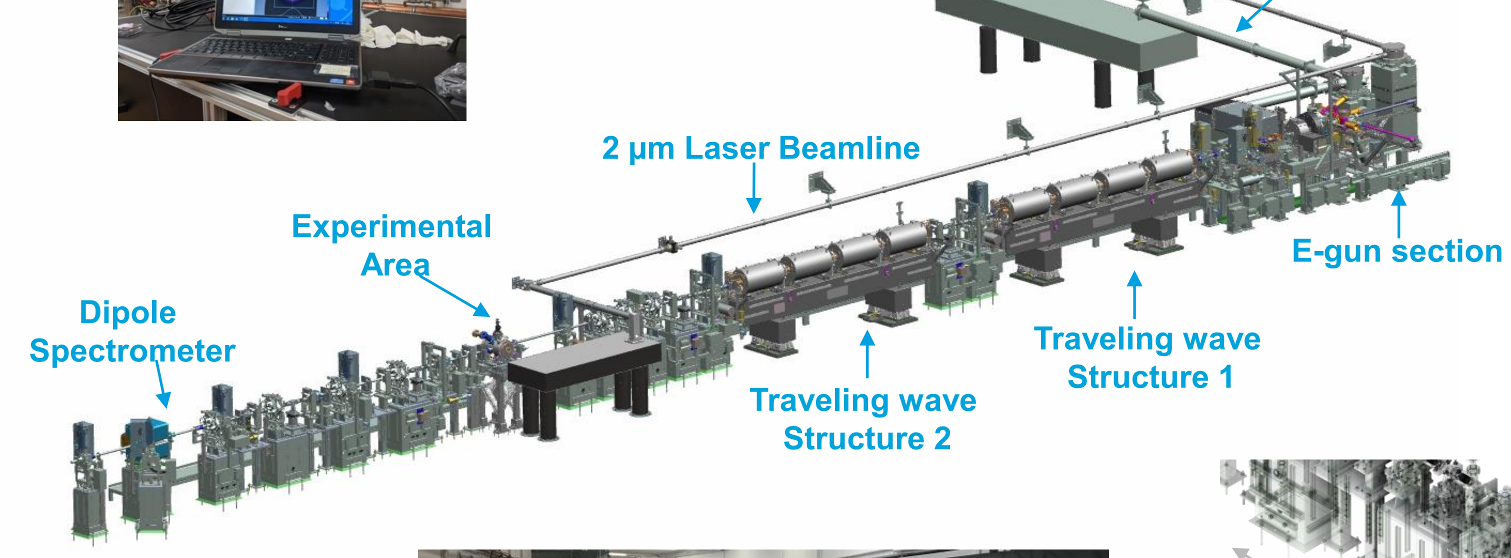
B.C. Stuart et al., Physical Review B, **53**, 1749 (1996).

Gain Shaping with Etalon

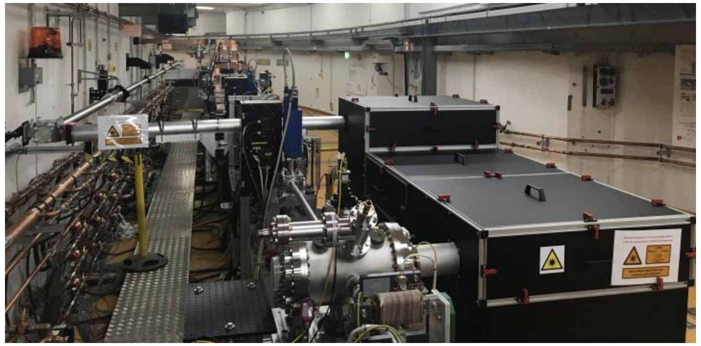


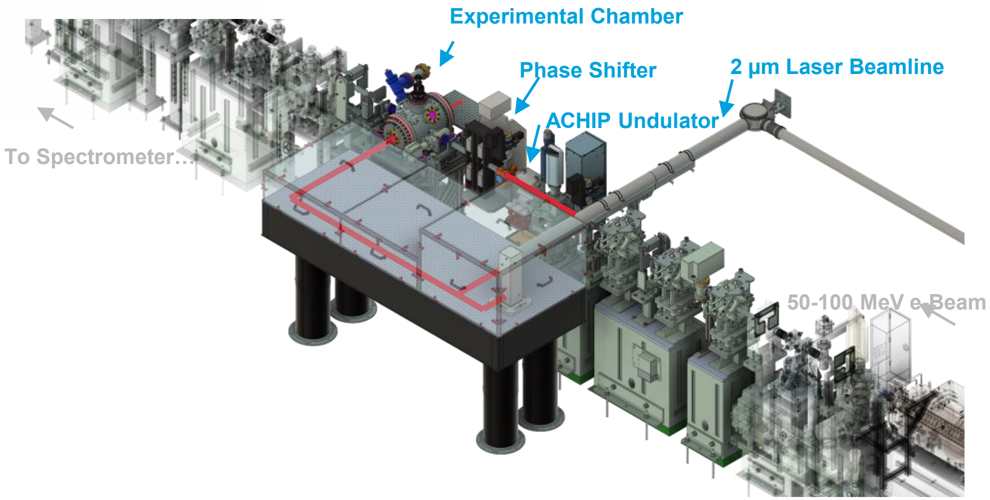
Beam transport





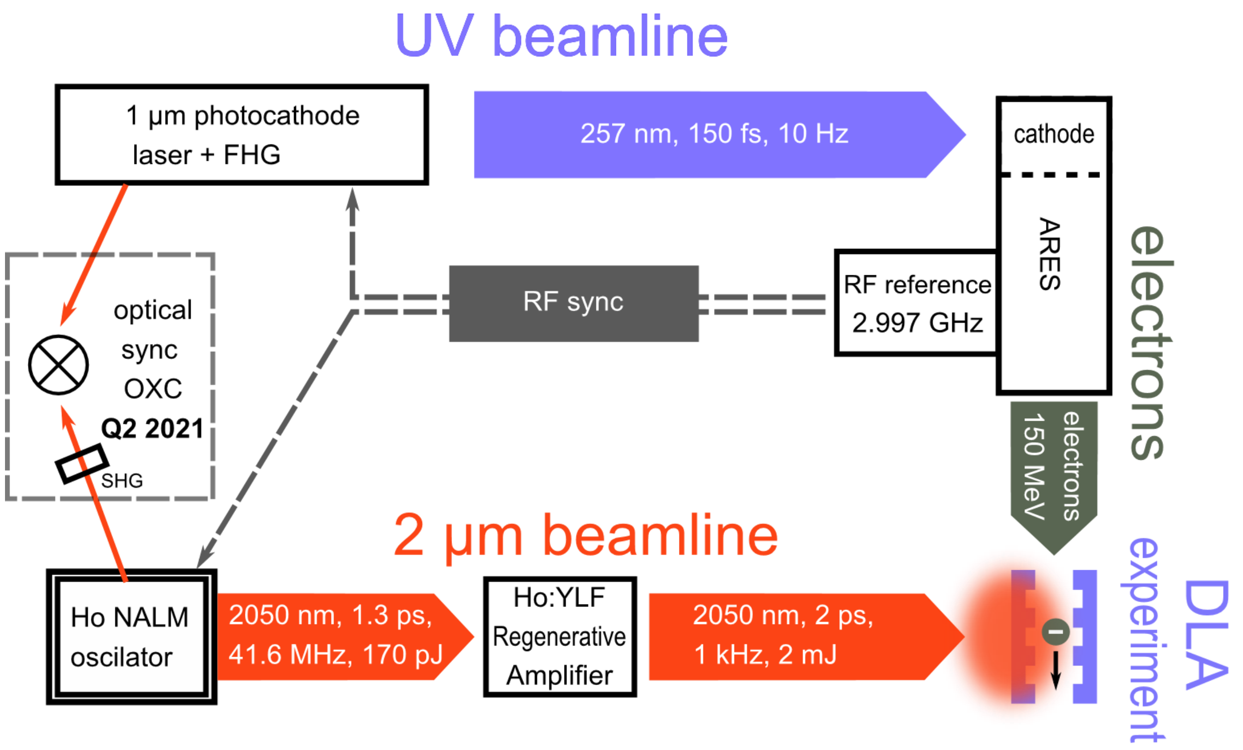
- Laser light delivery via vacuum beamline with **4f relay imaging system**
- Distance from source to target is ~31 m.
- Active beam stabilization system



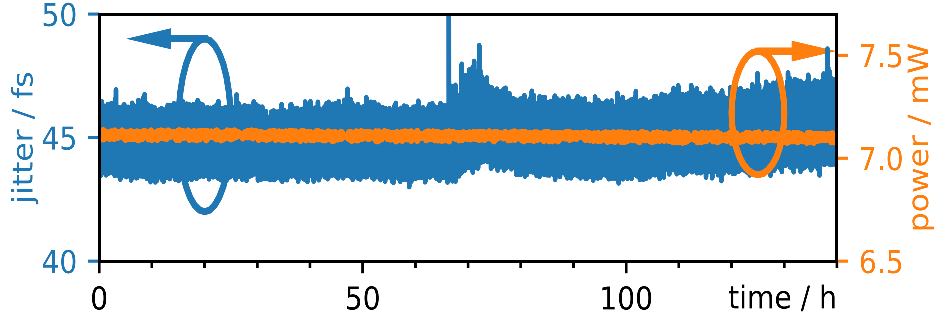


Synchronization

- Both lasers (UV + 2 µm) are locked to the machine RF
- RF to optical synchronization:
  - photodiode signal is filtered and mixed with reference
  - Digital phase-locked loop using digital IQ demodulation M. Felber, et al., Proc. of IPAC 2012, p. WEPPD048.
  - Digital locking scheme allows time shift of laser pulses



2 µm oscillator locking performance



- In long-term operation jitter <50 fs (RMS)

Planned improvements

- We identified pump laser intensity noise as major contribution to timing jitter → **new low noise pump**
- **Optical synchronization:** to improve the relative timing between electrons and the 2 µm laser, a **balanced optical cross-correlator** will be installed in Q2 2021

Summary and outlook

- We constructed/installed a synchronizable a 2 μm laser system for DLA experiments
  - Fiber oscillator
  - Regenerative Amplifier
  - Beam delivery over 30 m + active beam stabilization
- Synchronization to accelerator RF demonstrated
- First tests and integration into control system done
- Update to improve synchronization in progress (Q2/2021)
- DLA experiments are foreseen for Q3/2021

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ACHIP

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