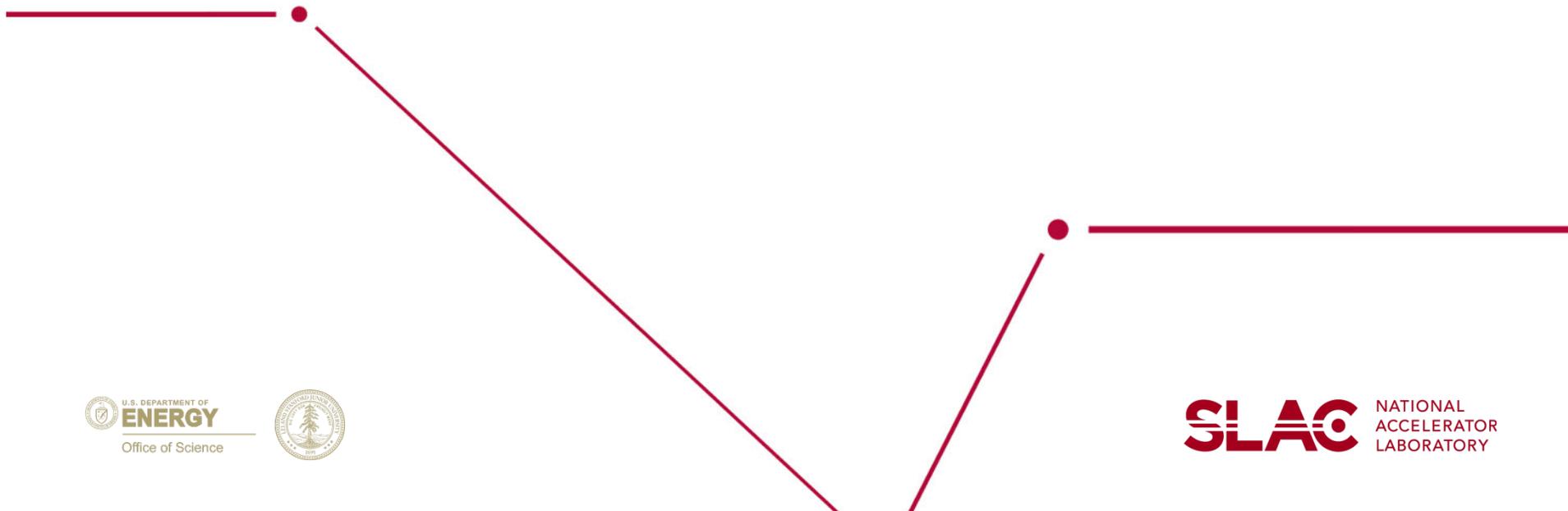


Dielectric Laser Accelerators Closeout Report (Working Group 7)

co-leaders: R. J. England, B. Cowan

Advanced Linear Collider Study Group (ALEGRO) Workshop
University of Oxford, UK March 26-29, 2018



Working Group 7 Participants



Many thanks to all participants for active and lively discussions!

Working Group Co-Chairs:

Joel England (SLAC)

Ben Cowan (Tech-X)

Participants:

Levi Schachter (Technion)

Jean-Luc Babigeon (CNRS)

Ang Li (FAU)

Norbert Schoenenberger (FAU)

Uwe Niedermayer (TU Darmstadt)

Andrzej Szczepkowicz (U Wroclaw)

Additional Helpful Discussions:

WG2 -- Andrei Seryi, Daniel Schulte

WGs 3, 6 – Jorge Vieira, Henri Vincenti, John Power, Phillipe Piot

WG7 Schedule

Tues March 27

9:00 - 10:15 Strategy and Prioritization

1:00 – 3:00 Joint session with WG3, WG6

3:30 - 6:00 Sources and Beam Transport

Wed March 28

10:45 - 12:15 IP Physics and Collider Parameters

1:30 - 3:30 DLA Technology Needs

4:00 – 6:00 WG Charge and Final Report Discussion

Working Group Charge Questions

- 1. Identify physics programme**
- 2. Identify scientific objectives and challenges**
- 3. Identify required high priority R&D, with possibly the construction of a test facility**
- 4. Identify an Advanced Accelerator Project (medium/long term)**
- 5. Identify partners and cost of R&D**

1. Physics Program

- WG1 HEP physics cases
- 100 to 250 GeV Higgs/Z factory, 30 TeV with $1e36$ luminosity

Megatable: Strawman 3 TeV CLIC-like scenario

Table 1: ALEGRO megatable – overall parameters of advanced acceleration collider concepts

Parameter	DLA	Concept 2	...	Concept N
Colliding species	e^+e^-	...	...	...
Upgrade or stand-alone	Standalone	...	...	...
Final E CM, TeV	3.0	...	...	...
Luminosity, $10^{34}\text{cm}^{-2}\text{s}^{-1}$	3.2	...	...	...
Effective L^* , m	5	...	...	...
Detector forward exclusion angle, mrad	...	...	...	...
Total length, km	9.2	...	...	...
Length of beam delivery, km	2.3	...	...	...
Repetition rate, Hz	20×10^6	...	...	...
Total wall plug power, MW	360	...	...	...
Colliding beam power, MW	22.9	...	...	...
IP beam sizes, X/Y, nm	1/1	...	...	...
IP beam length, Z, mm	0.32	...	...	...
IP beam n-emittance, X/Y, nm	0.1	...	...	...
IP beam E-spread, %	1	...	...	...
Colliding bunch population, 10^{10}	0.00047	...	...	...
Initial E of colliding bunches, GeV	1500	...	...	...
Driver type	laser	e-bunch	p-bunch	...
Adv.acc. media	diel	diel	...	...
Driver E/bunch, J	3.0	...	...	...
Adv.acc. transformer ratio	N/A	...	...	...
Length of single adv.acc stage, m	8×10^{-7}	...	...	...
Number of adv.acc stages	1.9×10^6	...	...	...
Effective gradient of adv.acc media	1 GV/m	...	...	...

- Performed preliminary 30 TeV scaling: crosschecks needed before ESG report
- Tradeoffs b/w IP spot size, emittance, rep rate, luminosity need further evaluation
- Gamma-gamma scenario also evaluated for Beijing ICFA 2017

2. Identify Scientific Objectives and Challenges

R&D Thrusts	Sub-Topics	Priority
1 Transport	Periodic focusing requirements for long-distance transport	High
	Radiation hardness and charging effects	High
	Wakefields - longitudinal and transverse - mitigation strategies	High
	BBU	High
	Start-to-end modeling	Med
	Halo and Beam Collimation	High
	Intrabeam Scattering of the bunch particles	Med
	Combining of multiple parallel beams	Med
Sub-micron coalignment over km distances	Med	
2 High-Field	Choice of Laser Wavelength	Med-Low
	Laser technical requirements	Low
	High-field damage mechanisms in dielectrics	Low
	SPM, Dispersion, and Raman Scattering	Med
	Stark band-splitting	Low
Heat dissipation at high laser rep rate	Med	
3 Sources	Electron sources	Med
	Positron sources	High
	Gamma-Gamma	Low
4 Final Focus	Requirements for final focus system	Low
	Luminosity, disruption, beamstrahlung	Low
	Requirements for dispersive microbunch smear-out	Low
5 Efficiency	Achievable laser wall-plug efficiency	Low
	Laser to dielectric coupling efficiency	Med
	Field to electron efficiency	Med
	Cost drivers and trends/projections	Med
	Linear collider power requirements; achievable beam power	Med

3. High Priority R&D and Future Test Facilities

Proposed High Priority R&D Studies for DLA Linear Collider:

Electron and Positron Sources (1-2 years)

Evaluate suitability of superconducting RF sources for electron and positron generation at MHz rep rates.

Are damping rings needed to achieve required emittances?

Does not preclude investigation of other advanced source technologies

Computation and transport studies (1-5 years)

DLA simulation is amenable to reduced model tracking like RF accelerators

Does not impose severe requirements on new computation hardware/software needs

Existing codes can largely be used: new DLA oriented tracking codes now available Initial design studies will be done as part of existing programs for few MeV case Extending to other structure designs and higher energies can then be conducted straightforwardly

Need to understand emittance increases due to nonlinearity of fields

This does not require simulating the entire km of structure since the beam breakup and emittance growth can be extrapolated from smaller (≤ 1 meter) simulations

DLA Specific IP physics questions (1-2 years)

Effect of optical microbunching on disruption, beamstrahlung, luminosity enhancement

Need for collimation, crab cavities at high rep rate (e.g. 20 MHz) acting on the microbunched train

3. High Priority R&D and Future Test Facilities

Current Test Facilities:

UCLA Pegasus: 1-8 MeV photoinjector+linac; Ti:Sapphire laser; low-charge with $n \sim 30\text{nm}$

High gradient and high energy gain demonstration experiments

Stanford MEOC (modular electron optics column): 100 keV SEM column for low-energy structure evaluation

FAU Erlangen: 30 kV SEM and supertip field emission source test stands; $2\mu\text{m}$ laser testing

Future Planned (Funded) Test Facilities (1 to 5 year timeline):

PSI SwissFEL 3 GeV beam line - dedicated DLA diagnostic and vacuum chamber

Laser driven undulator, wakefield studies, radiation damage testing

DESY SINBAD beamline -- short bunches (few fs); optically microbunched beams anticipated

Net acceleration experiments; particle deflection/streaking

FAU and Stanford: 1 MeV university test bench: demonstrate basic staging and integrated component capabilities; proposed outcome of ACHIP

Other Potential Test Facilities (1 to 5 year timeline):

NLCTA (SLAC) – currently in minimal operation mode; may become available for limited tests

ATF -II (BNL) – high power CO_2 laser; capabilities for hosting advanced accelerator experiments

4. Advanced Accelerator Projects (Medium/Long Term)

Medium Term (2-5 Years)

Microbunched Beam Test Facility – conventional or novel linac for DLA tests

→ Emittances, bunch charge suitable for DLA + variety of other experiments

→ Tunable laser and dedicated optical microbunching (or multiple lasers at several wavelengths from 1 to 10 microns)

→ 30 MeV to 1 GeV; rep rate not critical; test bed for evaluating LC capabilities: net acceleration, emittance preservation, transport, wakes, beam dynamics

→ Possible candidate locations: SINBAD, NLCTA, UCLA Pegasus

Long Term (10 Years)

DLA Linear Collider Test Facility – 1 GeV DLA prototype

→ Part of the ANAR roadmap as intermediate step to a full scale linear collider;

→ Evaluation of DLA scaling to high energy with multi-stage integration;

→ Radiation and laser safety likely requires national lab infrastructure

→ Variety of possible auxiliary applications: attosecond undulator radiation in X and EUV; XFEL superradiant emission; ultrafast microscopy and atomic science

5. Partners and Projected R&D Costs

CURRENT ACTIVE PROGRAMS: ACHIP (multiple PIs), Euclid Tech Labs, U. Tokyo (Uesaka), LANL (Simakov), UCLA (Rosenzweig)

Candidate Working Group Core Participants

(Preliminary, requires confirmation)

Joel England, Ben Cowan, Bruce Carlsten, Tor Raubenheimer, Peter Hommelhoff, Levi Schachter, Pietro Musumeci, Uwe Niedermayer

Additional Interested Parties: Jean-Luc Babigeon, Andrzej Szczepkowicz

External Experts: Mitsuru Uesaka, Jay Dawson, Phillip Russel, Andrei Seryi, Daniel Schulte, Roman Poeschl

5. Partners and Projected R&D Costs

Funding levels of existing programs provide some guidance:

ACHIP - \$13.5M over 5 years = \$2.7M/year (very low overhead ~ 12%)

LANL - \$3M over 3 years = \$1M/year

SLAC, DESY, PSI: National Lab in kind support (~\$1.8M/year)

Combined follow on program(s) should be at similar effort level to maintain critical mass:

May be subdivided into parallel programs at partner institutions under multiple funding sources.

Assumes funding from usual funding agencies (50 to 60% overhead)

Due to low overhead of Moore Foundation gift grant, a continuation program would need ~ 2x current funding for equivalent effort level

Also note differences in Europe vs US - PIs/Staff do not charge to the grant

Summary

Key Advantages of DLA:

Linear acceleration mechanism in a static structure with vacuum channel.

Critical technologies (laser development, nanofab) already near LC requirements.

Unique bunch format (fC charge at 10 to 50 MHz rep rate) reduces beamstrahlung.

Efficiency calculations are promising with reasonable wall plug power consumption.

Major Challenges for a DLA Collider:

Small beam apertures → challenge with regard to wakes, halo, and long-distance transport.

Need high-rep (10 – 50 MHz) low charge (fC) normalized emittance (< 1 nm) e- and e+ sources.

Funding for this area of research is limited and not directly focused on HEP applications.

Takeaway Points:

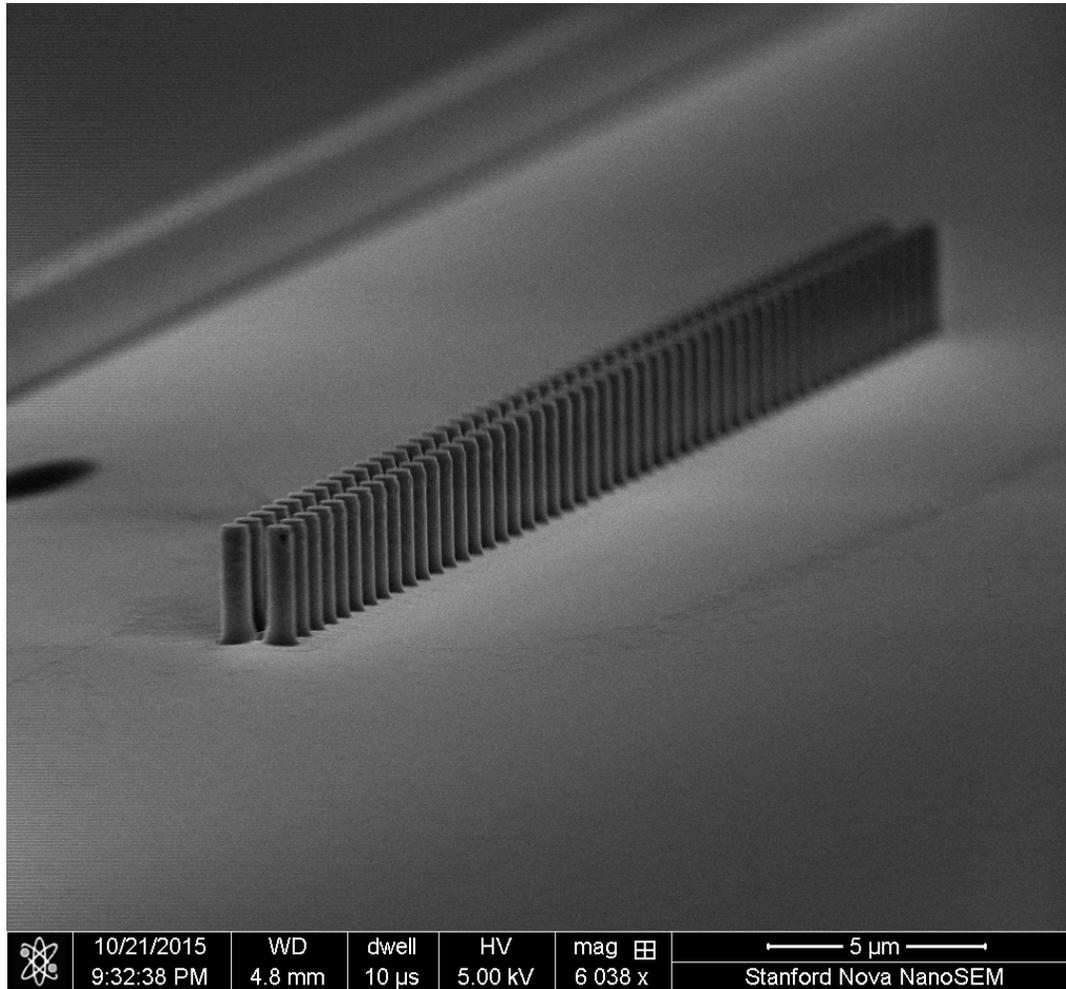
DLA has compelling advantages that position it as a competitive LC technology

Requirements of a LC impose major technical challenges for all advanced concepts

DLA's challenges are distinct from other concepts but not necessarily less surmountable

Thank you to the **ALEGRO** organizing committee and we look forward to seeing you at Breckenridge in August!

SLAC



Dual pillar DLA accelerator (Stanford)