The Advanced Superconducting Test Accelerator (ASTA) facility at Fermilab

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ASTA overview

This cavity is currently at A0

<40 MeV

< 750 MeV

< 1 GeV

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ASTA phases

• FY12: photoinjector commissioning +250 MeV

• FY 13-14: install commission ACC2+3

• FY 15: 750 MeV beam to “users”

beam manipulations?
more accelerations?

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ASTA promise...

• Variable energy from \(~40\) to \(~1\) GeV,

• High-repetition rate (1-ms trains):
  - Exploration of dynamical effects in beam-driven acceleration methods.

• L-band SCRF linac:
  - Well suited for beam-driven acceleration,

• Photoinjector source:
  - Provides low-emittance beam,

• Arbitrary emittance partition:
  - repartition of phase spaces to match final applications,
  - Tailored current profiles.

(ISTA performances are extrapolated from simulations of injector -- these are the best possible performances)

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Accelerator configuration for 1st beam

- Only one accelerating module available for first beam,
- Transport from cryomodule exit to spectrometer line with FODO
- High-energy spectrometer + user beamline(s)
- Off-axis dump to accommodate possible extensions

[C. Prokop, et al., (2011)]
Initial research themes:

• Beam dynamics
  • Photoinjector characterization,
  • Low energy compression.

• Advanced phase space manipulations:
  • Flat beams and their compression,
  • Transverse-to-longitudinal phase space exchange (PEX),
  • Arbitrary repartitioning of emittances (flat beam + PEX)

• High-brightness electron beams
  • Channeling radiation (with Vanderbilt),

• Integrable-Optics Test Accelerator (Valishev’s et al.)
  • Small diameter ring downstream of cryomodule to test integrable optics concept.
High-Brightness e- beams: possible production of field-emitted bunches

- During FY12-13, HBESL will support the development of a coaxial-line cathode holder
- Two-frequency gating of field emitters
- If successful this system could be used at ASTA

[collaboration with Vanderbilt and NIU (funded by DARPA)]

[J. Lewellen, PRSTAB 2006]
High-Brightness e- beam: applications to X-ray sources

- Bright electron beams from single-tip FE are planned to be used to produce X-rays via channeling radiation
- Expected brightness for 15 keV \( \sim 10^{12} \) photons/s-mm\(^2\)-mrad\(^2\)-0.1% BW
- Need 40 MeV bunches on a diamond crystal with \(~1000\) e-

FE array cathodes could also be used to increase charge/bunch or open new manipulation opportunities (combination with phase space exchangers)

Next generations phase-space exchange (PEX) experiments

• Precise control of phase spaces
• Phase space exchange between two degrees of freedom was pioneered at Fermilab (A0 photoinjector)
• At ASTA we plan on pursuing and applying this concept to advanced acceleration techniques and novel accelerator-based light sources
Towards next generation light sources

- Combining Fermilab’s phase space manipulation expertise with novel acceleration schemes
- Compact short-wavelength (soft x-ray?) FEL

50-MeV low-charge photocathode filament for witness bunch

(adapted from Jing, Power, and Zholents APS/ANL)
Combining field emitters with PEX beamlines

• Generation of train of attosecond bunches,
• Applications to short wavelength light sources (FEL, ICS,…)

[Graves, Kaertner, Moncton, Piot to be published (2011)]
Integrable-Optics Test Accelerator

- ASTA facility provides the needed infrastructure to test other concepts,
- IOTA, a compact ring dedicated to test integrable optic (with ORNL),
- No stringent requirements on ~150-MeV beam quality,
- Can support experiment of optical stochastic cooling. (with MIT)
Further developments

- High-brightness beams
  - channeling radiation
  - femtosecond bunch trains
  - short-wavelength light sources
  - FEL

- Advanced phase space manipulations
  - current shaping
  - emittance repartitioning
  - Beam-driven acceleration

- Integrable Test Optics Accelerator
  - Optical stochastic cooling
  - Compact THz CSR source?

Multi-dimensional Cooling?
Summary

• Over the last decade, Fermilab has been an active player in photoinjector R&D and application to AARD:
  - e-source for linear collider + short-wavelength FELs,
  - novel phase space manipulations: flat beam, emittance exchange, current tailoring technique.

• Phase space manipulations pioneered at A0PI have many applications: beam-driven acceleration, light sources, ...

• ASTA: will incorporate most of these manipulations ⇒ flexible, powerful facility to support a vibrant AARD program

• A0PI: will be transformed into a high-brightness electron source laboratory (HBSEL): [A future talk at the AEM]
  - explore novel cathodes and acceleration concepts,
  - support gun R&D to improve the performances of ASTA.