STELLA
Staged Electron Laser Acceleration

STI OPTRONICS

STELLA-II Experiment Update on Monoenergetic Laser Acceleration

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ATF Users' Meeting
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STELLA Collaborators

- STELLA team consists of collaborators from several institutions
  - Marcus Babzien (BNL)
  - Ilan Ben-Zvi (BNL)
  - Lora Campbell (STI)
  - David Cline (UCLA)
  - Christian Dilley (STI)
  - Juan Gallardo (BNL)
  - Steve Gottschalk (STI)
  - Ping He (UCLA)
  - Karl Kusche (BNL)
  - Richard Pantell (Stanford U.)
  - Igor Pogorelsky (BNL)
  - David Quimby (STI)
  - John Skaritka (BNL)
  - Loren Steinhauer (UW)
  - Arie van Steenbergen (BNL)
  - Vitaly Yakimenko (BNL)
  - Feng Zhou (UCLA)
- Newest STELLA collaborators
  - Russian Academy of Sciences: Nikolai Andreev, Sergei Kuznetsov, and Alla Pogosova
  - Hebrew University: Arie Zigler
  - Naval Research Laboratory: Antonio Ting

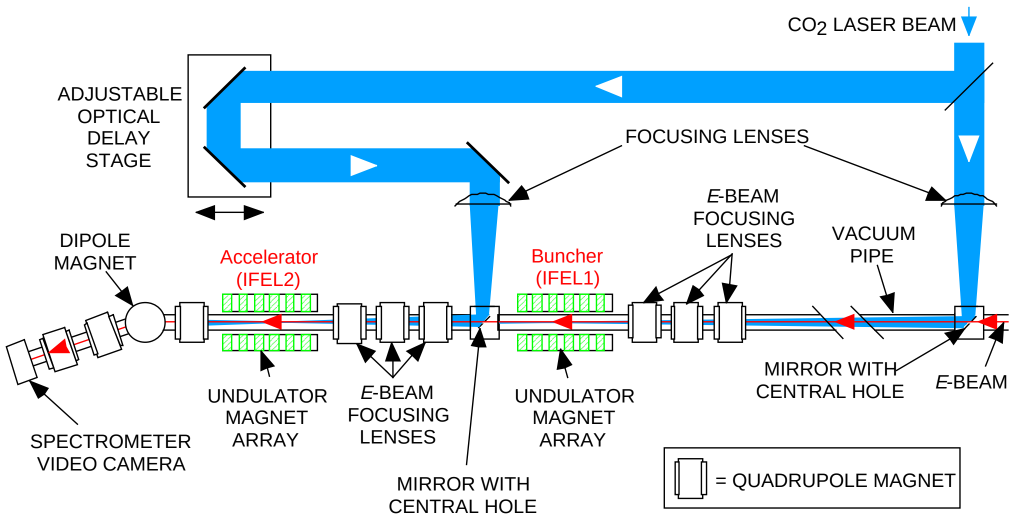
Staged Electron Laser Acceleration

Outline

- Introduction
- Staged Electron Laser Acceleration (STELLA-II)
  - Description of experiment
  - Present status
  - Near-term plans
- Results of Workshop on Staged Laser Acceleration, Dec. 4-6, 2001, Tucson, Arizona
- Closing remarks

STELLA Demonstrated Staging of Laser Acceleration Process

- Staging process demonstrated for first time during Staged Electron Laser Acceleration (STELLA) Experiment*
  - Used inverse free electron laser (IFEL) as laser acceleration mechanism
  - IFEL buncher (IFEL1) creates femtosecond microbunches
  - IFEL accelerator (IFEL2) accelerates microbunches



*W. D. Kimura, *et al.*, Phys. Rev. Lett. **86**, 4041-4043 (2001).

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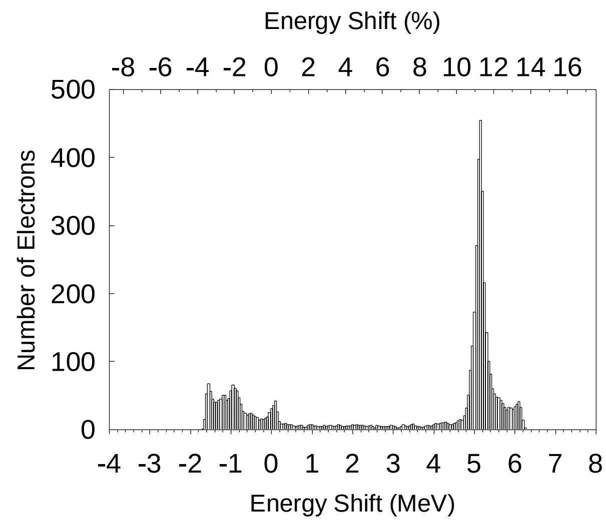
STELLA-II Builds Upon Success of STELLA

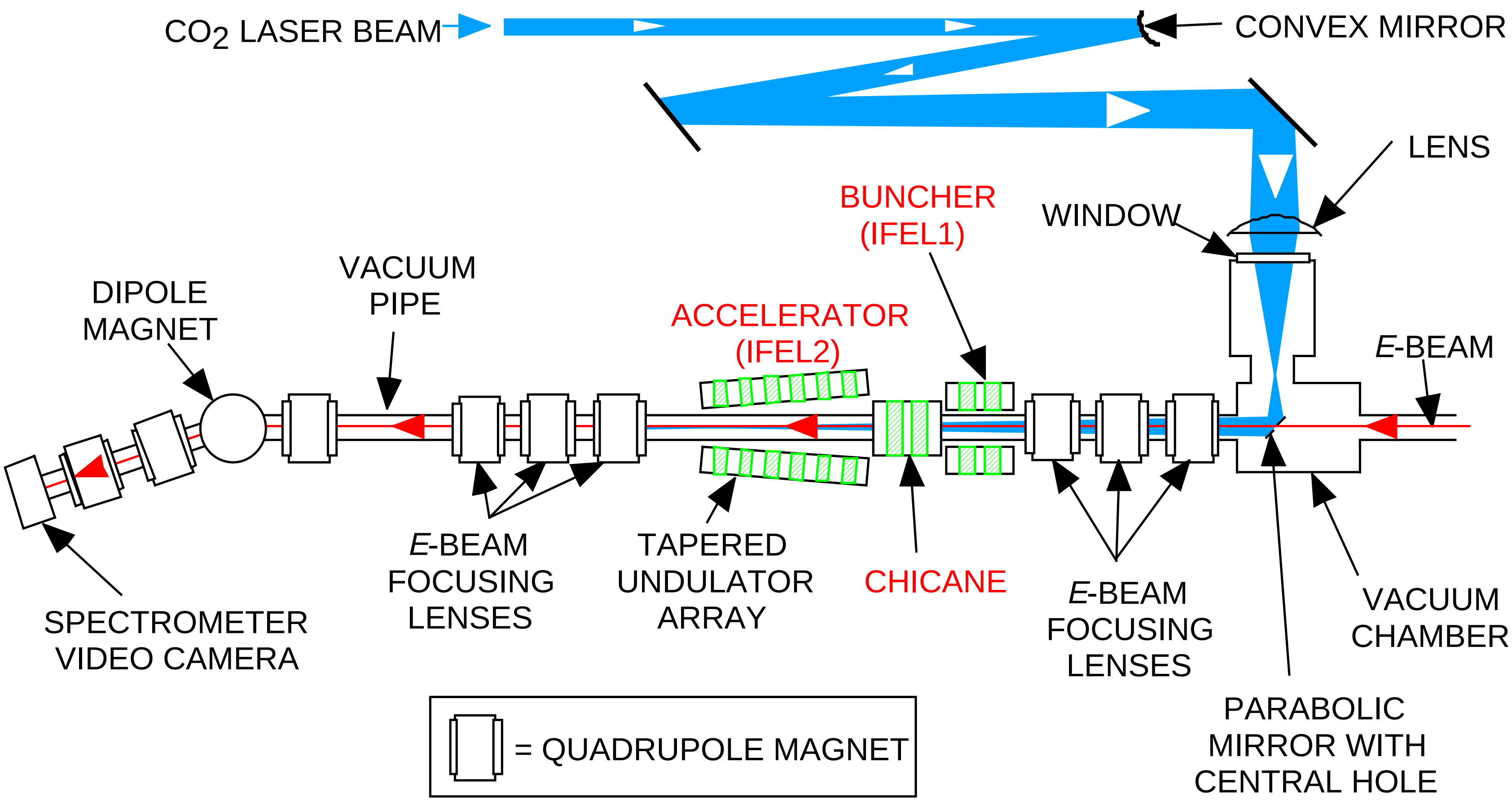
- Primary goal of STELLA-II is to demonstrate staged <u>monoenergetic</u> laser acceleration
- STELLA-II will be one of first to examine monoenergetic laser acceleration
  - Use single laser beam to drive both buncher and accelerator – greatly reduces phase jitter
  - Use tapered undulator in accelerator + high laser power (≥10 GW) – enables clean separation of accelerated microbunches while maintaining narrow energy spread

Model prediction at optimum phase delay

11% gap taper
P_L = 10 GW
E = 46.5 MeV
$B_{buncher}$ = 250 G
$B_{chicane}$ = 6290 G



Schematic of STELLA-II Experiment



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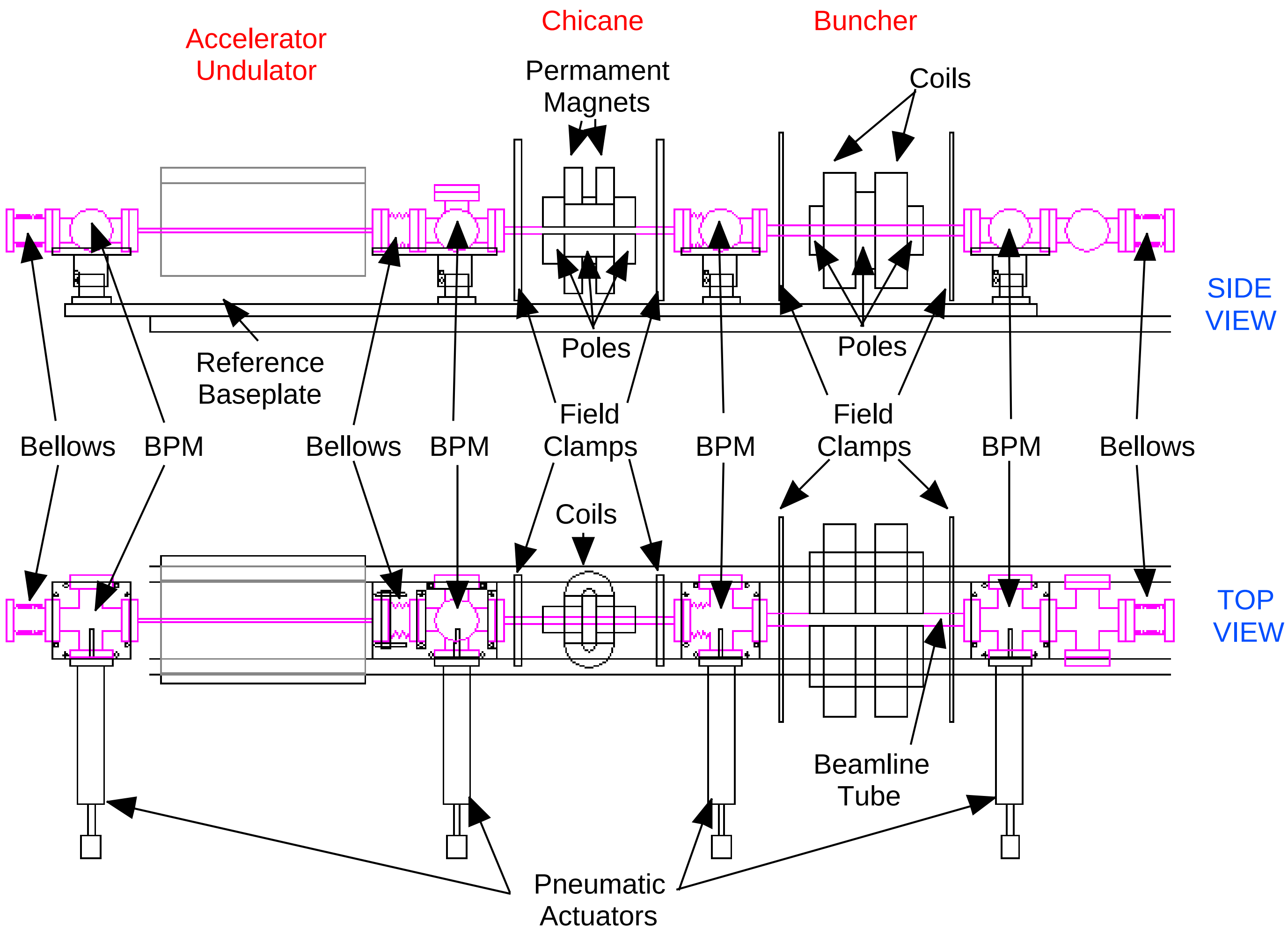
Sketch of STELLA-II Beamline



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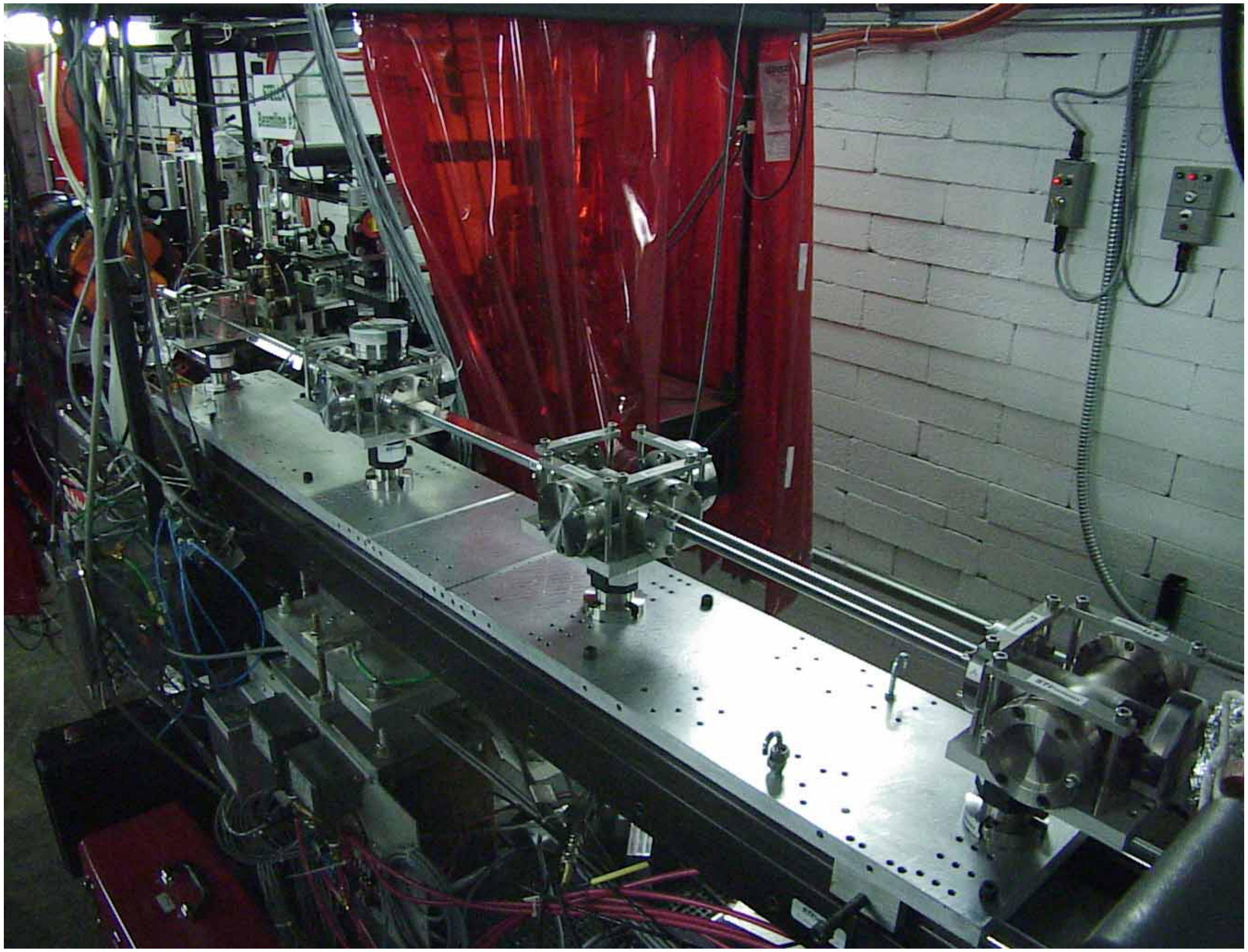
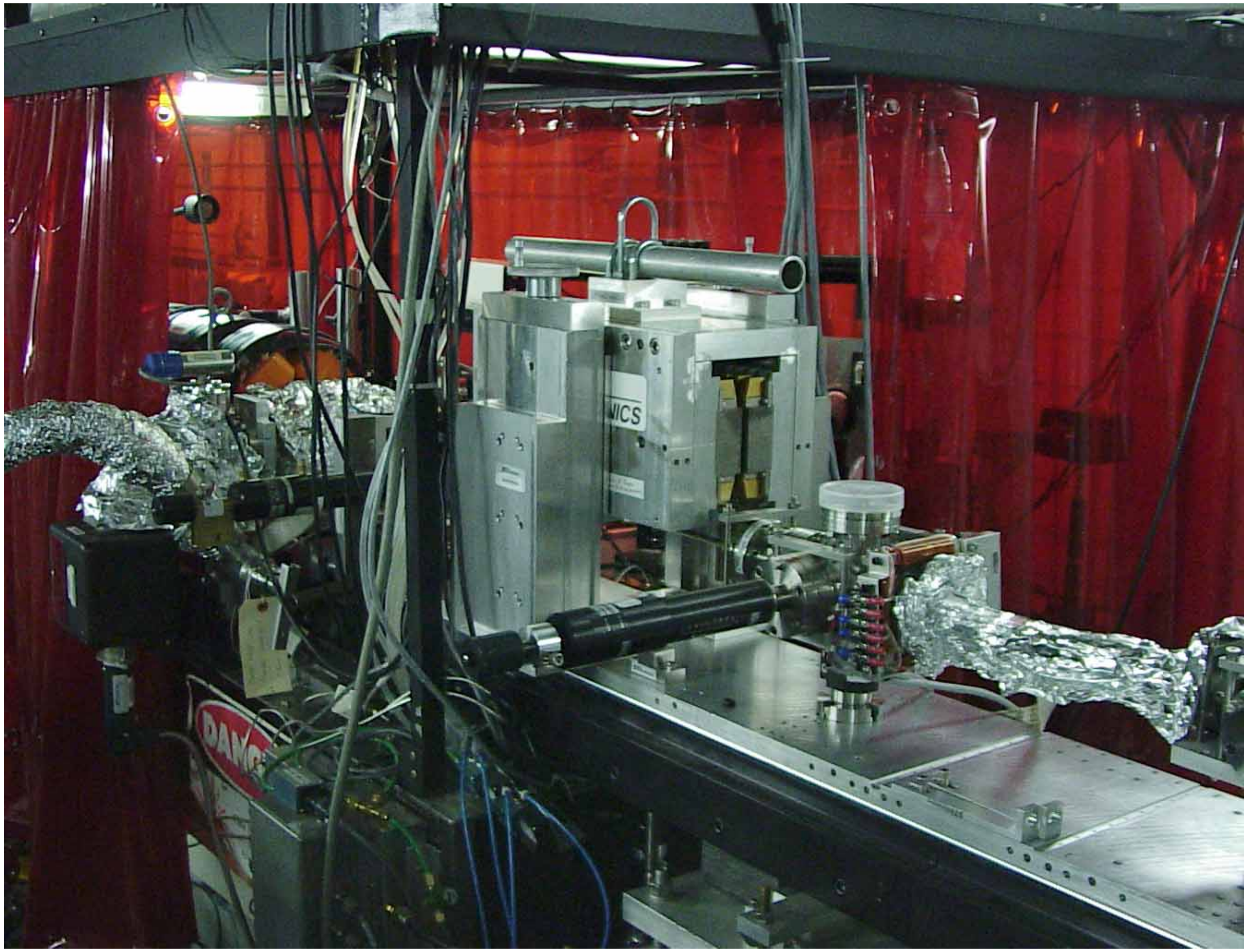
STELLA-II Beamline and Baseplate



Undulator (Accelerator) on Beamline



Photograph of Buncher

- Single-period electromagnet
  - Purpose is to modulate *e*-beam energy by ±0.5%
  - High laser power means little B-field needed
  - Features wide gap to accommodate short laser beam Rayleigh range

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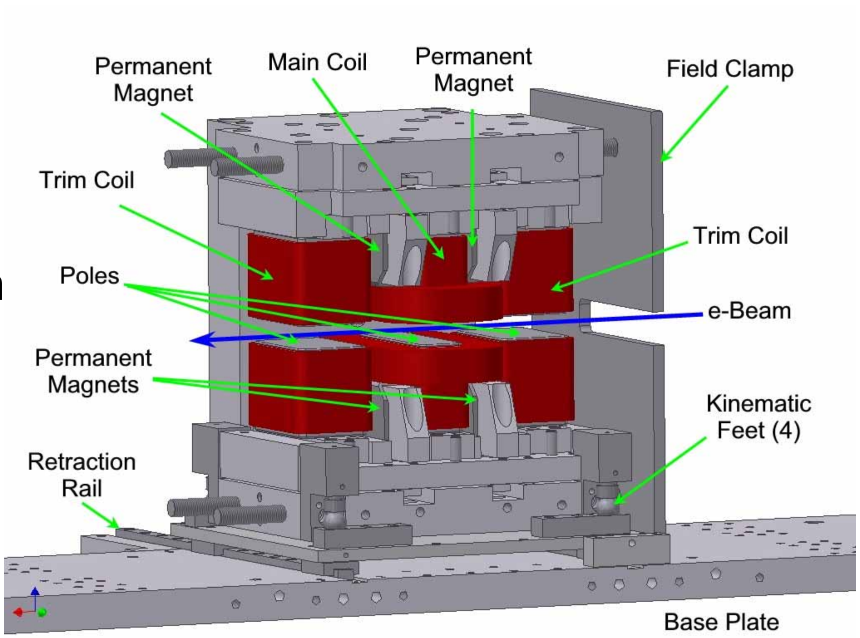
3-D Drawing of Chicane

- Hybrid electromagnet/permanent magnet device
- Serves two purposes
  - Permanent-magnet field chosen to cause bunching at accelerator (eliminates 2-m drift space between buncher and accelerator during STELLA)
  - Electromagnet allows fine adjustment of phase delay between arrival of microbunches and laser pulse in accelerator undulator (replaces optical delay plate used during STELLA)



STELLA-II Hardware Being Tested & Laser Transport Being Upgraded

- New beamline vacuum pipe and diagnostic ports installed
  - Located where STELLA-I IFEL1 (buncher) previously positioned
  - *E*-beam successfully tuned through new beamline
- Untapered and tapered undulator already tested individually
  - Plan to initially use 11% gap taper (one of highest tapers ever tested)
- Buncher and chicane need to be tested next
- Laser transport system being upgraded to permit delivering higher laser power
  - Need short Rayleigh range for high laser intensity in undulator and to prevent optical damage of optics
  - Laser beam to enter beamline through lid of Smith-Purcell chamber
  - Large diameter mirrors already available, other custom optics ordered, (NaCl window and lens)

Near-Term Plans

- Buncher installed on new beamline
  - Still need to verify proper operation
- Support hardware for new laser beam transport system currently being designed and should be fabricated by latter part of February
  - Optics should be delivered at same time
  - Assemble new laser beam transport system in February
- In February, finish assembly, testing, and installation at ATF of chicane
- Test new laser beam transport system together with individual STELLA-II components beginning in March
  - ATF CO_2 amplifier should be ready to deliver $\geq$10 GW
  - Finish individual testing of buncher and chicane
- Begin fully integrated experiments in March/April

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Results of 2001 Workshop on Staged Laser Acceleration

- Purpose of STELLA 2001 Workshop
  - Examine issues related to performing STELLA-II experiment
  - Develop ideas for staging other laser acceleration methods, such as laser wakefield acceleration (LWFA)
  - Discuss related issues, such as plasma channels suitable for staging
  - Examine other new types of acceleration mechanisms, such as novel vacuum acceleration
- Workshop was very successful and productive
  - Experimental issues related to STELLA-II and vacuum acceleration discussed
  - LWFA experts (Andreev and Ting) provided valuable input on possible new staging ideas
- New collaborations more firmly established
  - Will use when developing ideas for next program following STELLA-II
  - Analysis already begun on several new ideas

Closing Remarks

- STELLA-II hardware coming into place nicely
  - Individual components tested thus far performing as expected
- Upgraded laser beam transport should enable delivering >4 J pulse energy
  - For 180 ps pulse length, corresponds to >20 GW
  - For ~10 ps pulse length, corresponds to 400 GW
- Monoenergetic laser acceleration can be demonstrated with only 10 GW
  - Plan to initially deliver ~10 GW
  - As higher peak power becomes available, can try larger taper
    - Maximum possible taper is ≈20% and requires at least 100 GW
    - Buncher can handle 100's GW (requires less B-field)
    - Chicane performance is not directly tied to laser power
- Expect this early spring to be another exciting time for STELLA!