Laser & Injector Upgrade for 4-Hall Operation

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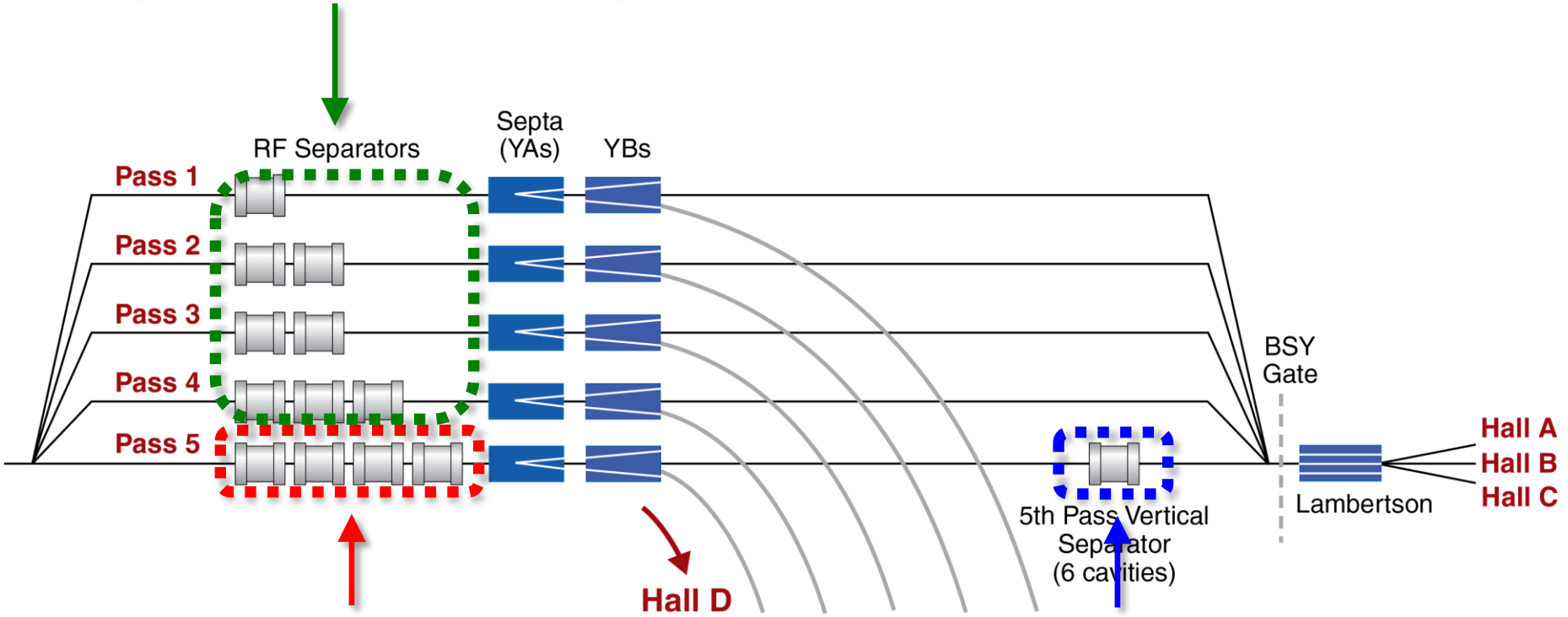
Operations Retreat

Outline

- RF separation for 4-Hall operation
- Injector beam generation
- Timeline and plans

RF Separation for 4-Hall Operation

Horizontal 1st- 4th Pass
499 MHz Separators
(kicks out Halls A, B, C)



Horizontal 5th Pass
750 MHz Separators
(kicks out Hall D)

Vertical 5th Pass
499 MHz Separators
(kicks out Halls A, B, C)

Constraint on LLRF/Laser System

Beam Condition	Hall D	Halls A, B, C
• Beam @ 1 - 4 passes	249.5 MHz	499* MHz (3-hall) 1 @ 249.5 MHz (4-hall)
• Beam @ 5th pass (Hall D OFF)	OFF	499* MHz
• Beam @ 5th pass (Hall D ON)	249.5 MHz	249.5 MHz

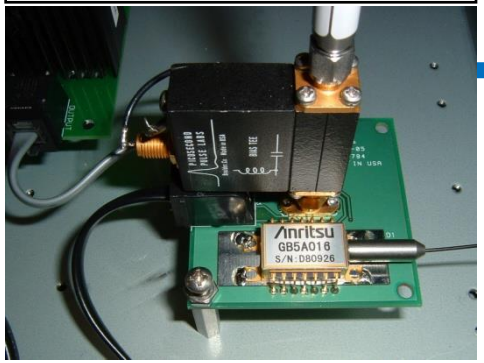
*Halls A, B, C can operate at 249.5 MHz generally if desired.

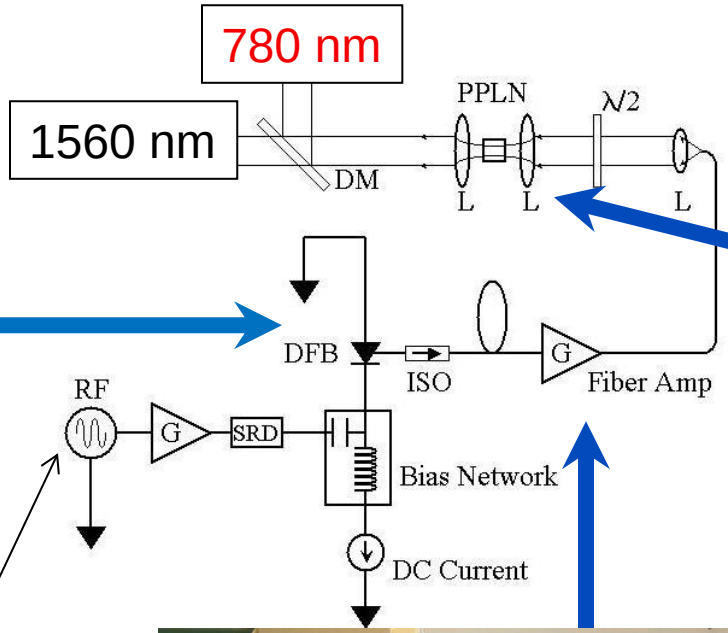
Major upgrade tasks

- Add a 4th fiber laser, combine with other 3 on laser table
- Generate bunch trains at both 499 and 249.5 MHz
- Achieve similar and reliable functionality at both rep rates
  - Means bunch length setup, procedures, mapping laser:rate:hall, etc.
- Demonstrate “sharing” of 3-beam chopper

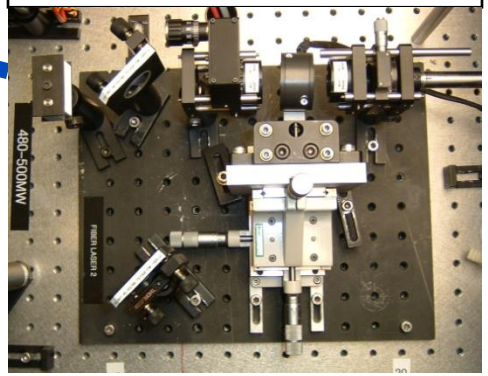
Synchronous Photo-Injection by Fiber Laser

RF Locked Low-Power
(1 mW)
1560 nm Fiber Diode

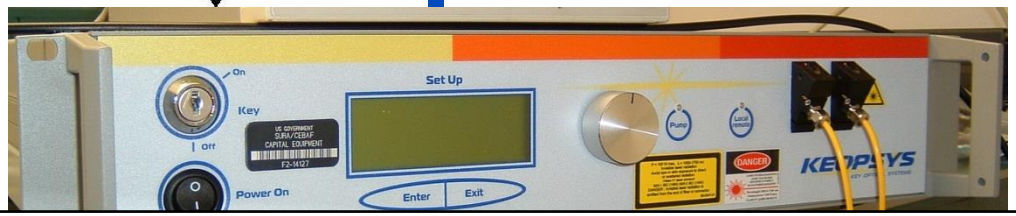




Frequency-doubler
1560 nm to 780 nm
30% Efficiency (2 W)



499 MHz

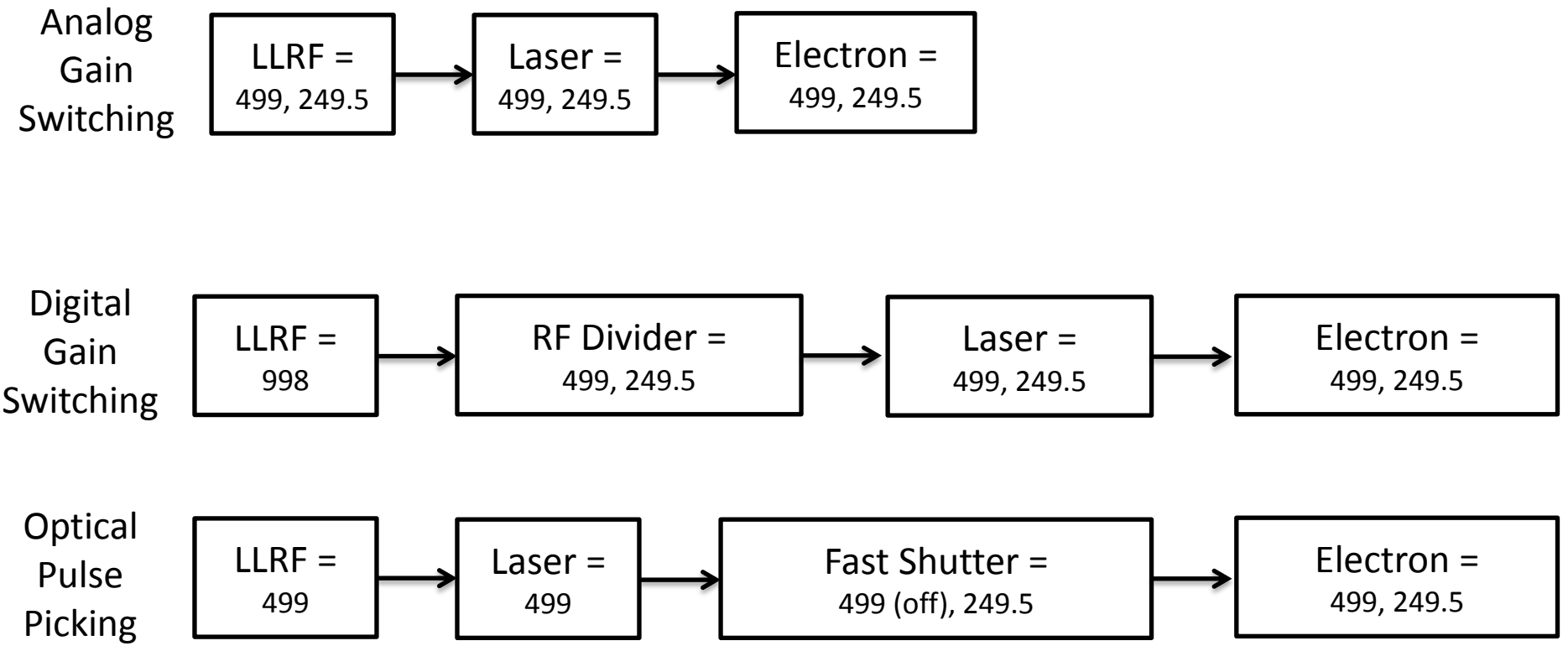


High Power (6 W) 1560 nm Fiber Amplifier

4-Hall operations requires building one more laser…

Beam Repetition Rate

We are considering three approaches to producing 499 and 249.5 MHz (also 31 MHz for Mott).



Laser Beam Spatial Combination

Laser beams must be spatially combined to illuminate the same location on the photocathode.

- **Polarization cube** – combine (s-, p-) orthogonal polarization with high efficiency e.g. when we must maintain high power (high current).

- **Dichroic mirror** – combine same λ with unequal (10/90) efficiency e.g. when we can sacrifice power (low current).

  For example:
  - Combine A+B with dichroic to s- state
  - Combine C+D with dichroic to p-state
  - Combine (A+B)+(C+D) with polarization cube

- Also being studied is combining beams by optical fiber

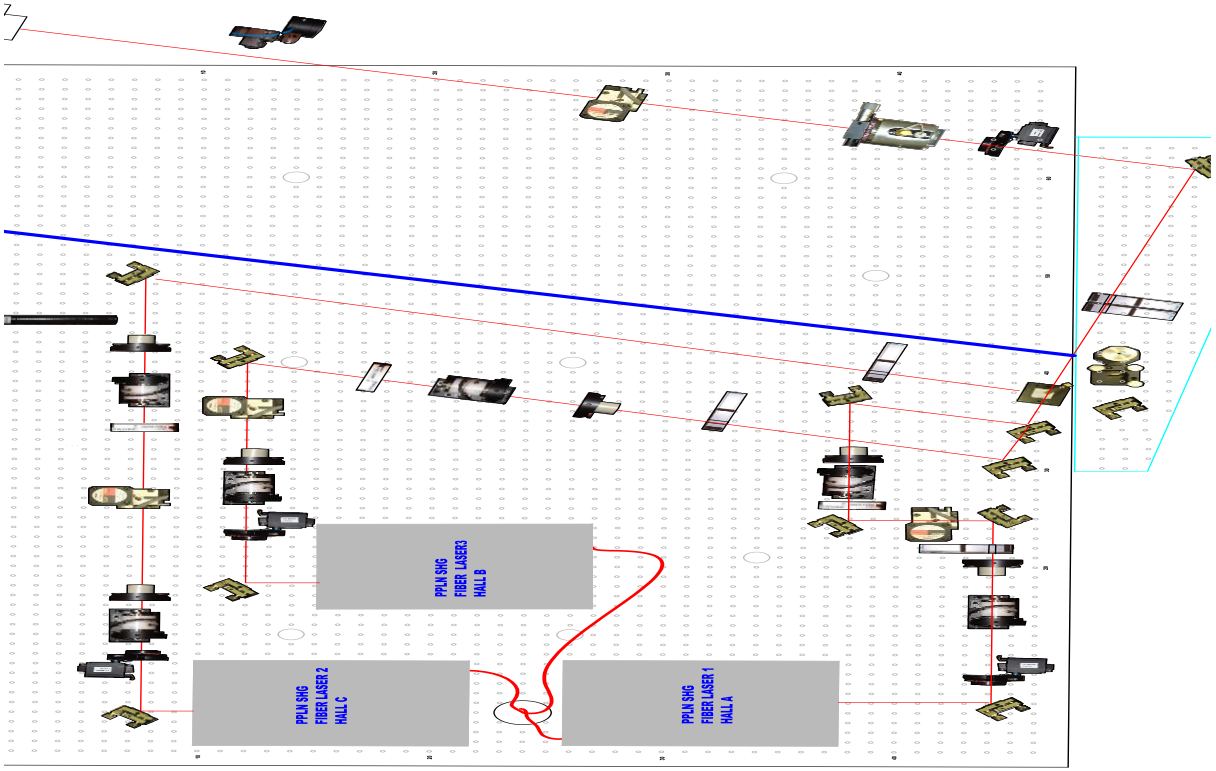
Laser Table Upgrade

MULTIPLE LASERS ON LASER TABLE…

- PPLN's (convert 1560nm to 780nm)
- PULSED MODE POCKELS CELLS
- INTENSIY (PQB) POCKELS CELLS
- BEAM SYNC ONLY SHUTTERS

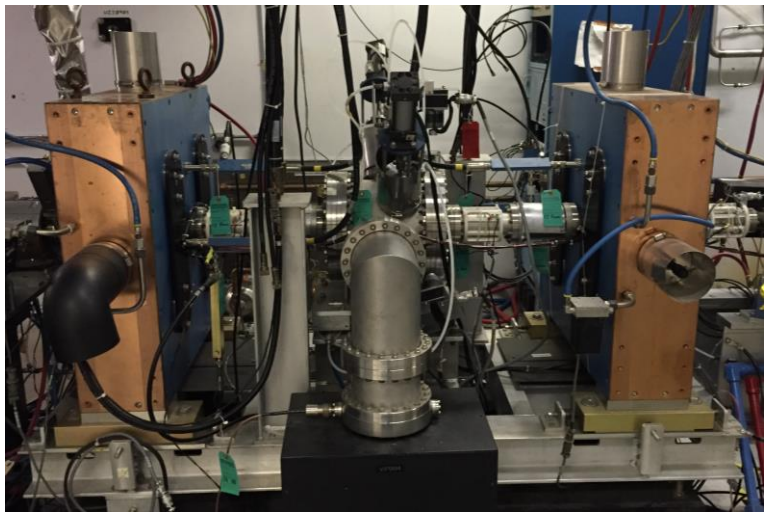
…ARE COMBINED TO SINGLE OPTICAL PATH

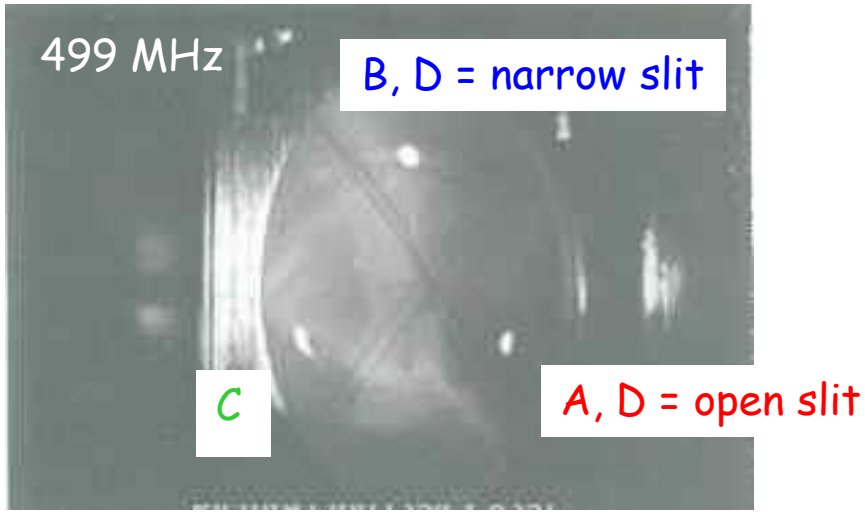
- PSS SHUTTERS
- POLARIZATION POCKELS CELL
- WAVEPLATE REVERSAL (IHWP)
- STEERING LENS



Beam Chopping

- The chopping system comprised of 3 physical “time window” apertures @ 499 MHz, defines the longitudinal acceptance.
- 3-hall operation allows each hall to have a unique aperture
- 4-hall operation requires two beams sharing one aperture
  - When D is low current 10’s-100’s nA can share with B
  - When D is high current 100’s-1000’s nA must share with A or C
- An alternative to sharing is to build a 250 MHz chopping system





Bunch Charge

The bunch charge is inversely proportional to repetition rate; halving the rep rate (499 MHz to 249.5 MHz) doubles the bunch charge.

Current	@ 499 MHz	@ 249.5 MHz
85 µA, max for 12 GeV	0.17 pC/bunch	**0.34** pC/bunch
180 µA, max for 6 GeV	**0.36** pC/bunch	0.72 pC/bunch

- Combined current to Halls A and C will be limited to 85 µA because of 1 MW total power limit.
- The bunch charge for 85uA @ 249.5 MHz has already been demonstrated during for QWeak.
- Injector Upgrade of gun operation from 130kV to 200kV will improve and extend capability for high bunch operation.

FY15 – Retrospective

- Halls A(249.5), B(499), D (249.5) achieved using Digital Gain Switching 998 MHz/2^N
- High bunch charge ~50 uA operation to Hall A @ 249.5 MHz achieved
- Operation at 249.5MHz suffered most from…
  - 180° phase shifts (locking 2^N division to LLRF)
  - Lack of 360° phase adjustment at 249.5 MHz exasperated this condition
  - Learning curve: new system & procedure to set phase (space charge, Mott, …)
- Other issues muddied the outlook…
  - Damaged amplifiers at lower rep rates (exceeded peak power)
  - Intermittent low frequency noise associated with seed laser digital TEC
  - Running in pulsed mode (familiarity w/ spatial profile from Pockels Cell)
- Ended run with standard Analog Gain Switching
  - Restored LLRF @ 499 MHz, but req'd additional hardware to make 249.5 MHz
  - Still lacked 360° phase shifting @ 249.5 MHz

FY16 – This SAD & Upcoming Year

- Laser system (Hansknecht)
  - Modular analog gain switching chassis (one for each laser, 3 now + 1 later)
  - Rack mounted chiller provides thermally controlled micro-climate
  - Restore analog seed laser TEC control
  - Communication to seed/pre-amp + IPG models (Johnson)

- LLRF (Plawski)
  - LLRF : up to 3 channels @ 249.5 MHz or 2 channels @ 499 MHz
  - Low cost solution bridges to final system in FY17
  - 360° phase shifting @ 249.5 MHz => delay line or firmware (Allison)

- Post SAD Priority is testing and development
  - Stable CEBAF system means efforts stay focused on final system
  - Evaluate performance & cost for reduced rep rate options
  - Test laser pulse pick-off PLL on bench for improving phase regulation
  - Test delivering two 249.5 MHz beams to BD, AD through 1 chopping aperture
  - Build new SCAM module for 4-laser operation (Flood)

FY17 – Ready for 4-hall Operation

- Install 4th fiber laser
  - Additional chassis in ISB
  - Additional laser amplifier in tunnel
  - Rework laser table (big job!)
    - ✓ Plan A – Laser combination by polarization/reflection
    - ✓ Plan B – Launching through a common fiber
  - Implement new 4-laser SCAM module

- LLRF/Repetition Rate
  - Plan A – multiple channels of 499/249.5 MHz LLRF channel
  - Plans B – digital gain switching or pulse picking
  - Phase control at 249.5 MHz
    - ✓ Requires phase lock at 249.5 MHz
    - ✓ Requires 360° phase control at 249.5 MHz
  - Implementing laser pick-off 499/249.5 MHz for stabilization improvement

- Implement software/controls for managing 4-lasers, 3-chopping apertures, 4-halls