Outfield ERL Option and Supporting R&D

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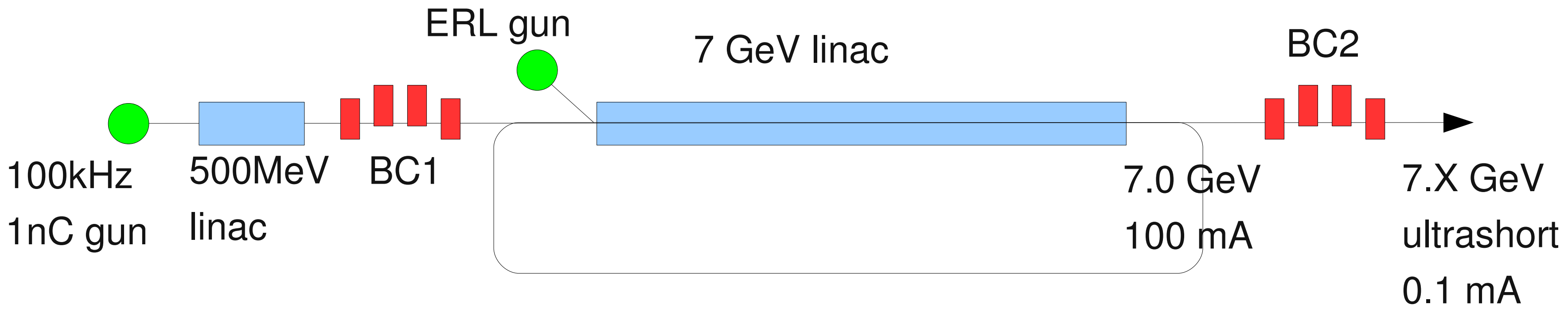
An "Outfield" ERL Option (G. Decker[1])

- Advantages:
  - Linac points away from APS[2] to give straight-ahead FEL hall[3]
  - Beam goes first into new, emittance-preserving turn-around arc[4]
    - *Potential for many new beamlines*
  - Avoids wetlands etc. by using narrow corridor for linac and return line
- Issues:
  - Big, expensive
  - North turn-around should be *larger* than shown
  - No place for very long undulators
  - Requires some changes to the ring

[1]G. Decker, "APS Upgrade External ERL Option," 9/27/06.
[2]M. Borland, "ERL Upgrade Options and Possible Performance," 9/18/06.
[3]M. Borland, "Can APS Compete with the Next Generation?", May 2002.
[4]M. Borland, OAG-TN-2006-031, 8/16/06.

Ultrashort Mode with Second Gun

- Bazarov[1] suggests that ultrashort pulses should be delivered with a separate gun to a separate user hall



- Due to low repetition rate of high charge gun, don't need energy recovery
- Limitation on average current is from beamloading
- Advantage: ERL runs normally for rest of user community
- Disadvantage: must build new beamlines for timing users.

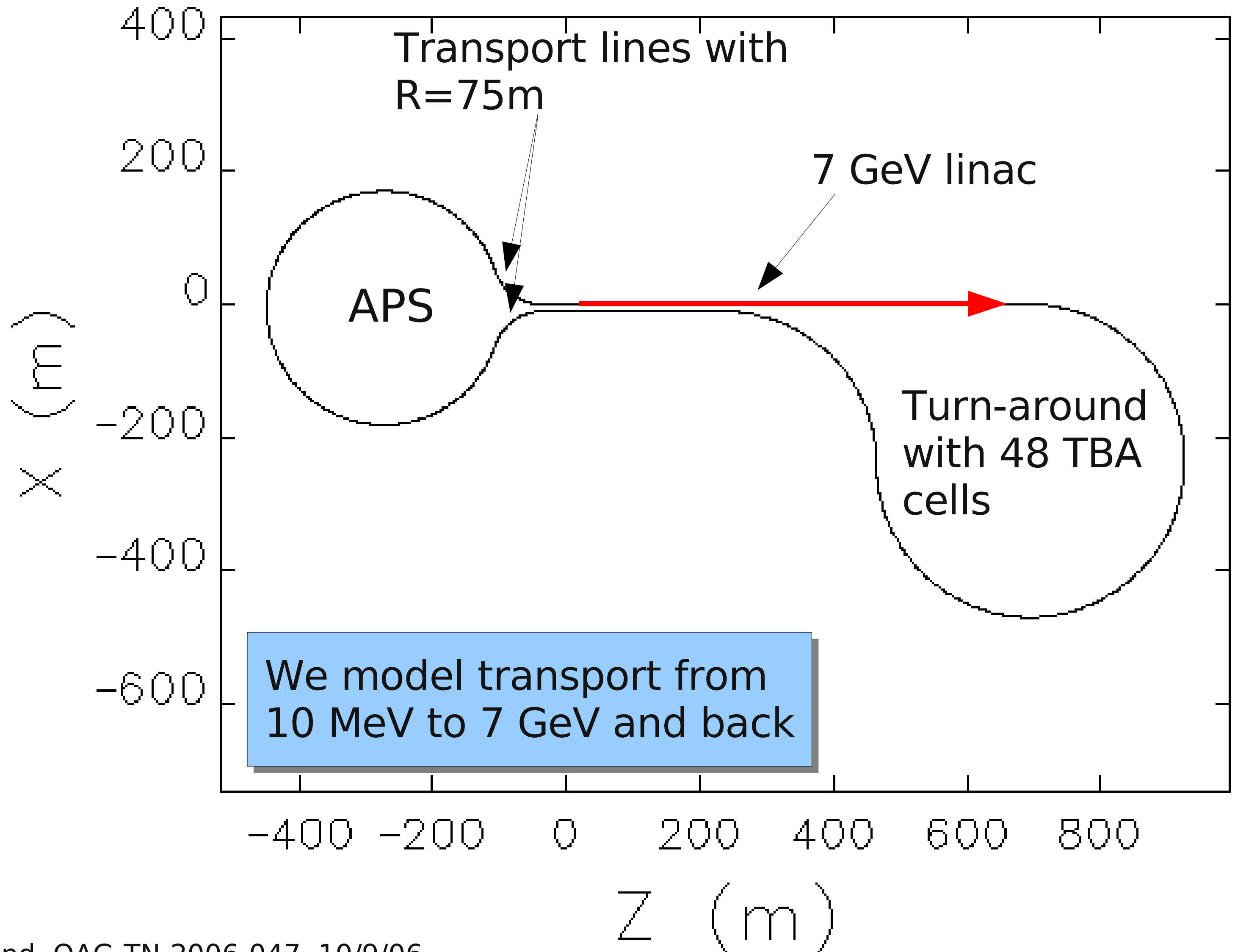
[1] I. Bazarov, private communication.

Required Ring Changes[1]

- All required changes are in Zone F (no beamlines)
- "Significant demolition" of Zone F shield wall required
- The ERL input and output transport lines will use straight sections now occupied by rf cavities
- We want to keep the cavities in the ring to allow stored beam operation
  - During commissioning period
  - For operational flexibility after commissioning
- Rf cavities can be relocated to other straight sections
  - Requires some new waveguide penetrations
  - Requires lengthening those straight sections
    - *New/modified vacuum chambers and supports*
    - *Beam emittance won't be as good as before.*

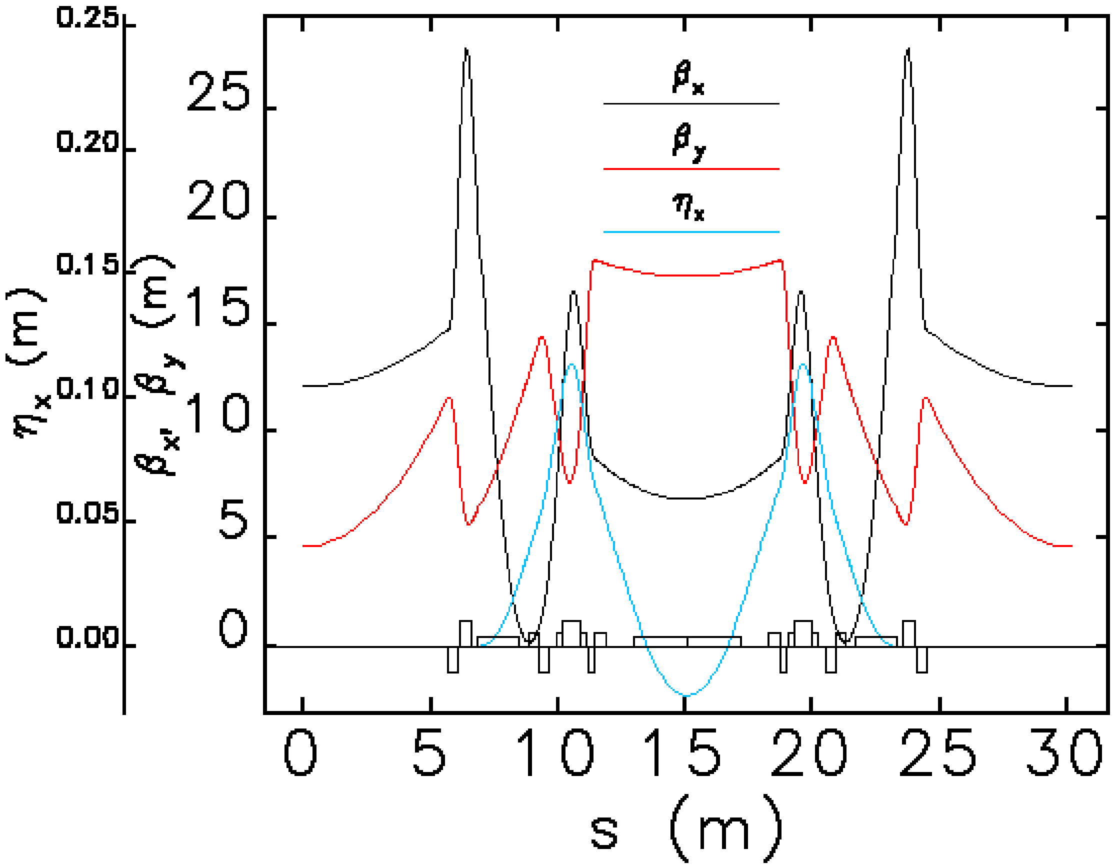
[1]G. Decker, "APS Upgrade External ERL Option," 9/27/06.

Realization of Decker's Outfield ERL Concept[1]



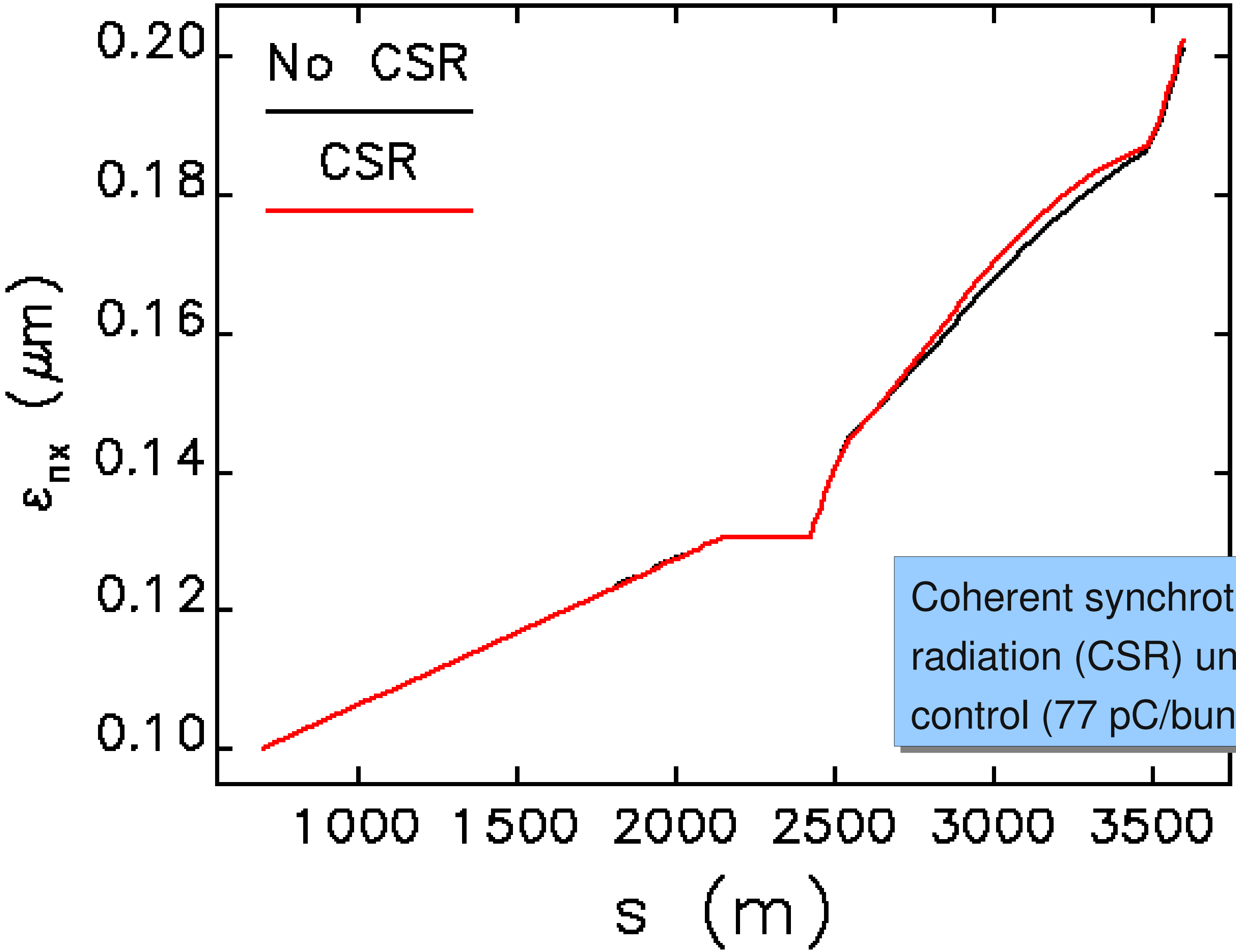
[1]M. Borland, OAG-TN-2006-047, 10/9/06.

Arc Design for Turn-Around



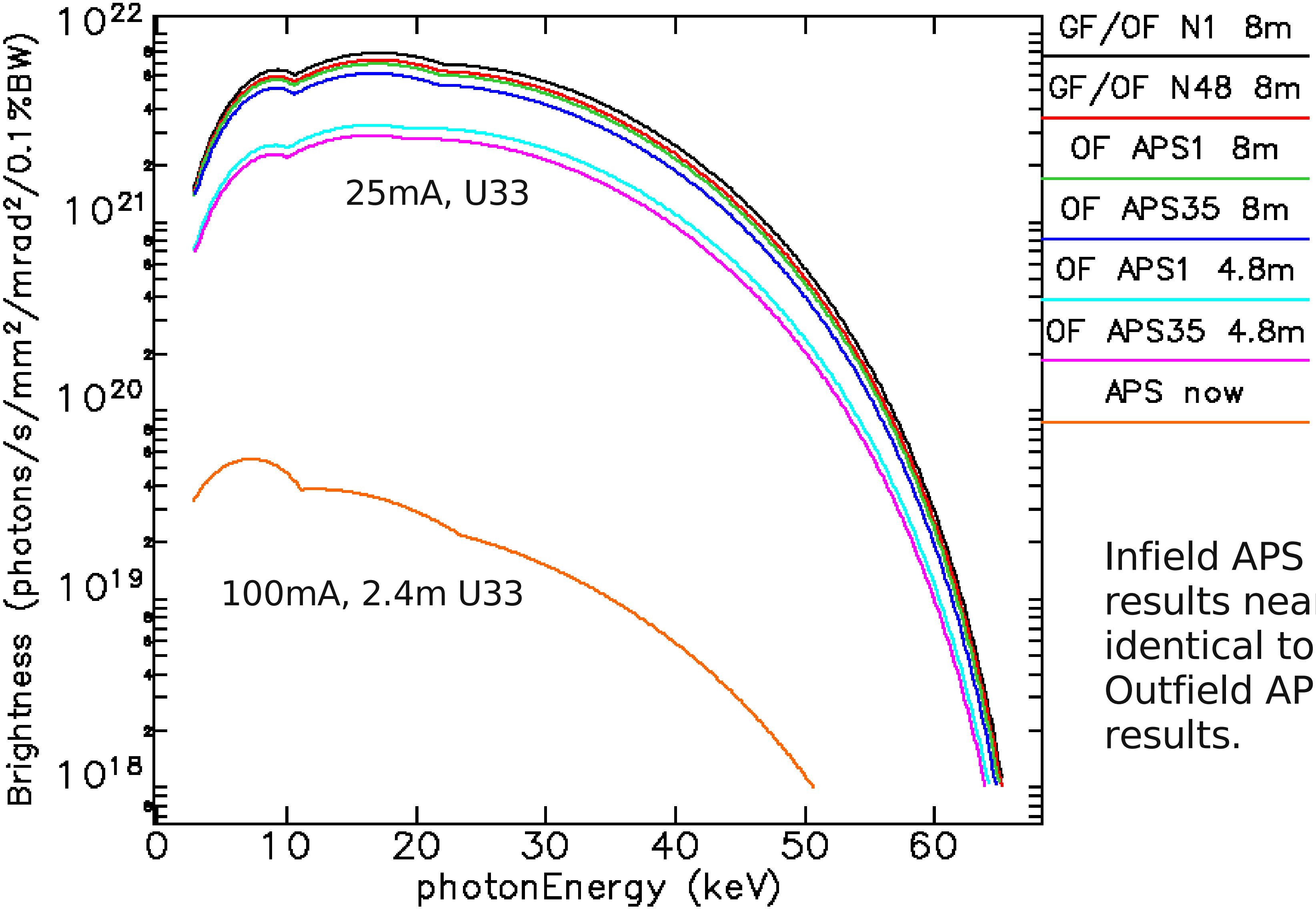
- Isochronous, achromatic triplet-bend cells
- Average radius 230m
- 10 m straights (like APS ring upgrades)
- Excellent emittance preservation
- Four sextupole families for beam loss control

Outfield ERL Tracking Results (7 GeV Portion)



Coherent synchrotron radiation (CSR) under control (77 pC/bunch)

Brightness Comparison for High Coherence Mode



Infield APS results nearly identical to Outfield APS results.

Computed with sddsbrightness (H. Shang, R. Dejus).

Most Important R&D Topics

- Gun design and low-energy beam transport
  - For now we've assumed values predicted by Cornell simulations[1]
  - Simulations at JAERI show comparable results[2]
- Cathode lifetime
  - Present-day cathodes can't sustain 100 mA for operationally-convenient length of time
- ERL performance is almost certain to be limited by these factors
- More in next talk.

[1] I.Bazarov and C. Sinclair, Phys. Rev. ST Accel. Beams 8 (2005) 034202.
[2] R.Hajima and R. Nagai, NIM A 557 (2006) 103-105.

Linac R&D Topics[1]

- Linac superconducting cavity design and fabrication
  - Required gradients (20 MV/m) and Q's (10^{10}) are achievable
    - *Total power dumped at 2 K is 16 kW*
  - Higher gradients would reduce length, but increase cryogenic power
  - Higher Q's would reduce cryogenic power
- Cryogenics
  - With present technology, ~16 MW cryogenic plant required
  - Better cryoplant design may be possible and might pay off[2]

[1]A. Nassiri, "ERL RF Systems", MAC Review, 11/15/06.

[2]M. White, private communication.

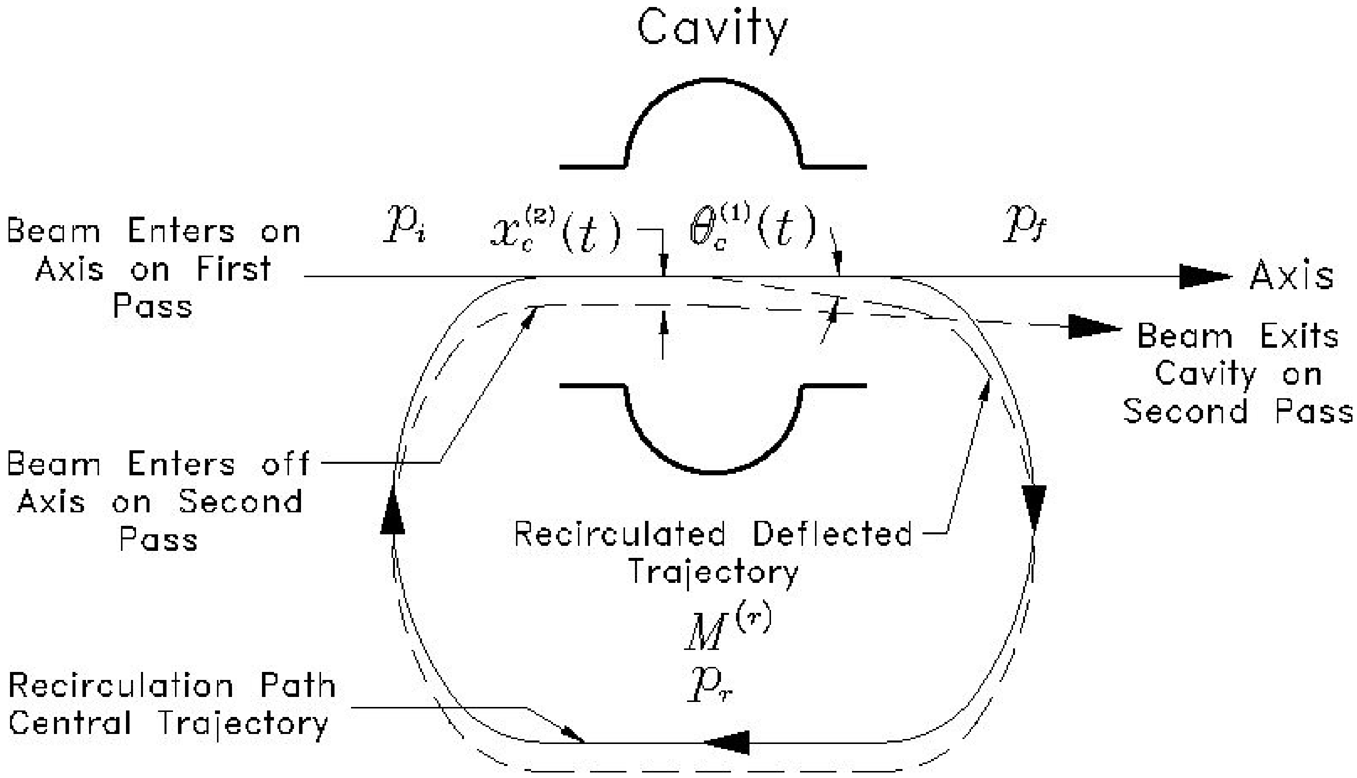
Linac R&D Topics[1]

- Linac cavity parasitic mode damping
  - Need dampers to remove energy from parasitic cavity modes
    - *Reduce parasitic heat loss at cryogenic temperatures*
    - *Increase current threshold for beam break-up*
  - Challenges are power handling and compactness
    - *High cavity fill factor can reduce length and conventional facilities costs*
- Linac optics design[2]
  - Optics and beam control issues are manageable
  - We have good solutions already.

[1] A. Nassiri, "ERL RF Systems", MAC Review, 11/15/06.

[2] M. Borland, OAG-TN-2006-041, 9/17/06.

Multipass Beam Breakup



N. Sereno, Univ. of Illinois Urbana Ph. D. Thesis, 1994.

Initially on-axis beam gets a small kick from HOM.

Beam returns with large offset that dumps more energy into the HOM.

Beam Instabilities

- Beam break-up appears manageable[1,2]
  - Damping of parasitic modes
  - Stagger-tuning of cavities
  - Proper linac/external optics design
  - A detailed APS-specific analysis needs to be performed
- Ion trapping[3]
  - Continuous trains of electron bunches at 1.3 GHz required to reach high current
  - These bunches attract residual gas ions, which can then disrupt the beam
  - Not a problem at APS, but ERL beams are much smaller.

[1] S. Gruner and M. Tigner eds., CHESS Tech. Memo 01-003.
[2] N. Sereno, "Beam Breakup in ERLs," 11/2/06.
[3] G. Hoffstaetter, private communication.

Beam Loss Issues[1,2]

- Possible problems include
  - Inefficient energy recovery
  - Cryogenic load in linac
  - Radiation hazard to users
  - Radiation damage to equipment
  - Catastrophic damage to equipment from beam strike
- APS injector delivers a mere 10 nA
  - Efficiency of charge transfer is 80 to 90%
  - “Maximum Credible Incident” is a 44 nA loss at one spot in ring
    - *11 rem/hour radiation outside shield wall*
  - Even 1 PPM loss from 100 mA ERL corresponds to 100 nA
- *Should we just run and hide from the ERL?*

[1] CY Yao, “Beam Loss Issues of ERL Accelerators,” 10/12/06.
[2] M. Borland and A. Xiao, OAG-TN-2006-052, 10/16/06.

Continuous Beam Loss Mechanisms[1]

- Beam halo, from many sources
  - Space charge
  - Scattered drive-laser light
  - Field emission
  - Gas scattering
  - Touschek scattering
  - Non-linear optical elements
- These are either
  - Present (mostly) at low energy
  - Controllable through proper design
- If we can collimate effectively at low energy, we may find losses are controllable
- Initial results show only Touschek is significant, but can be controlled[2,3].

[1]CY Yao, "Beam Loss Issues of ERL Accelerators," 10/12/06, and references therein.
[2]M. Borland, "ERL Parameter Review and Physics Issues," MAC Review 11/15/06.
[3]M. Borland, "Comparison of ERL Options and Greenfield ERL," MAC Review 11/15/06.

Conclusion

- An ERL external to the APS provides many advantages
  - Revolutionary x-ray brightness and coherence
  - Expansion to new beamlines
  - Straight-ahead option for short-pulse applications (e.g., FEL)
- We have basic designs that appear to deliver on these promises
- R&D required on many topics, including
  - Magnet design
  - Impact on stored beam mode (e.g., emittance)
  - Control of beam losses
  - Control of beam break-up and ion trapping
  - Linac cavity design, including cryoplant issues
  - Injector emittance
  - Cathode lifetime.