Unclassified

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Progress on the High-Current Superconducting Injector and Energy Recovery Linac at BNL

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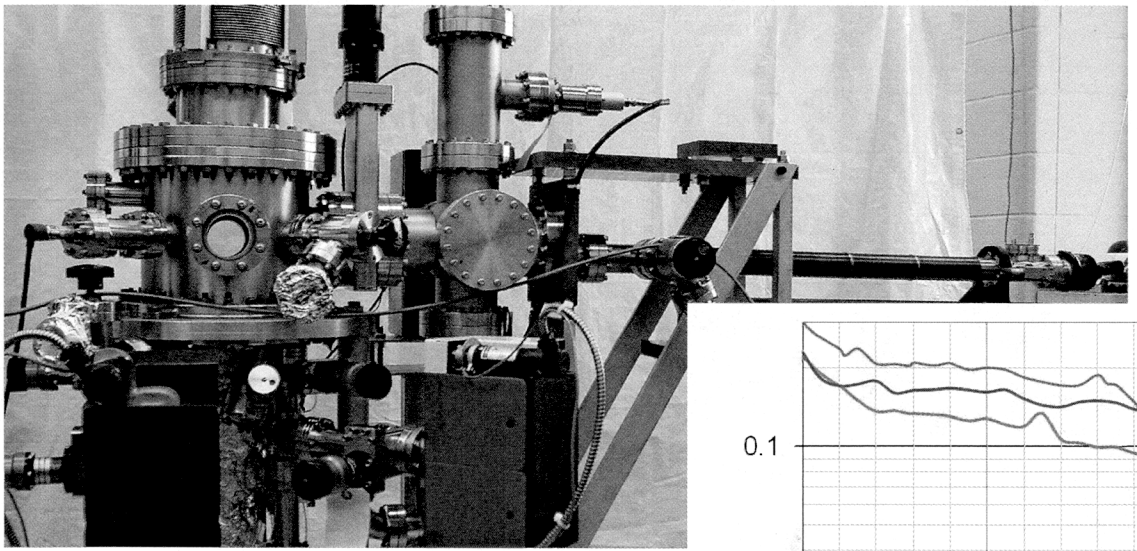
BNL/DOE background

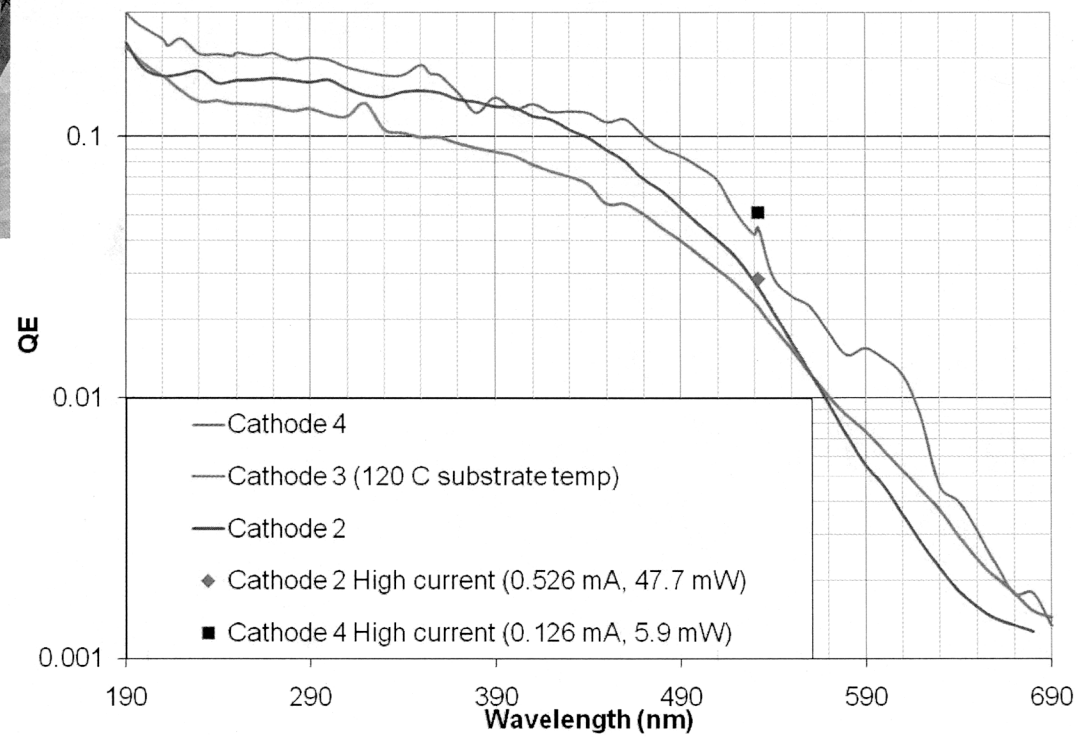
- Ampere-class Energy Recovery Linac (ERL) is of interest for many applications.
- At BNL we are interested in electron cooling of RHIC and Electron Ion Collider.
- These applications require up to 0.5 ampere CW current with low emittance.
- BNL and its industrial partner AES are constructing a high-current ERL.
- This will demonstrate the feasibility of high-current ERLs, reduce risk and cost.

TECHNICAL ISSUES

- The highest current demonstrated by now in SRF ERLs is ~ 10 mA at JLab.
- A 50 to 100-fold increase in current is a major technical issue. Items of concern are:
  - Preventing Beam Break-Up (BBU)
  - Disposing large Higher-Order Mode (HOM) power.
  - Avoiding disastrous beam loss in the system.
  - The unexpected.
- These issues cannot be laid to rest without a demonstration.

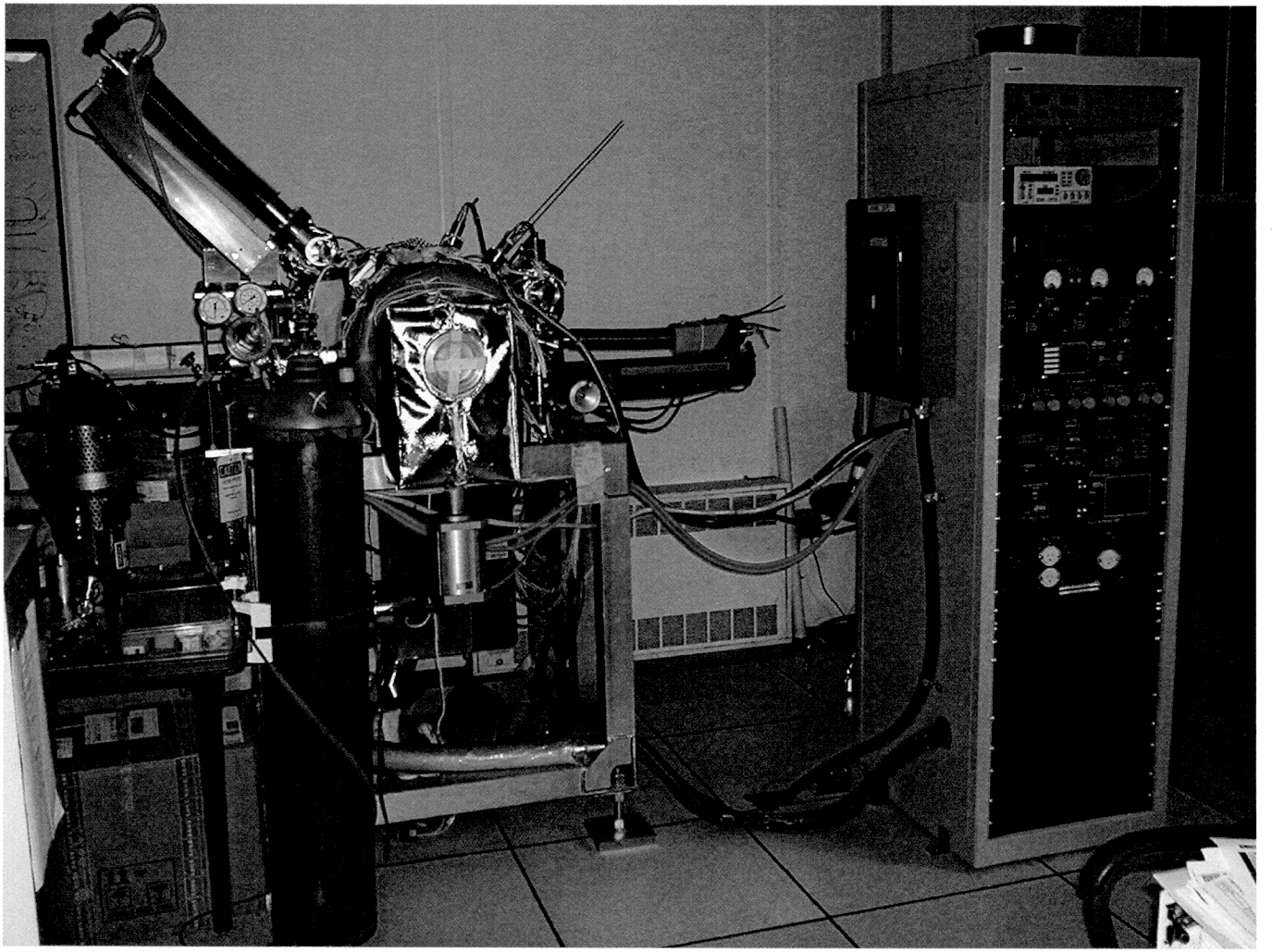
Photocathode R&D



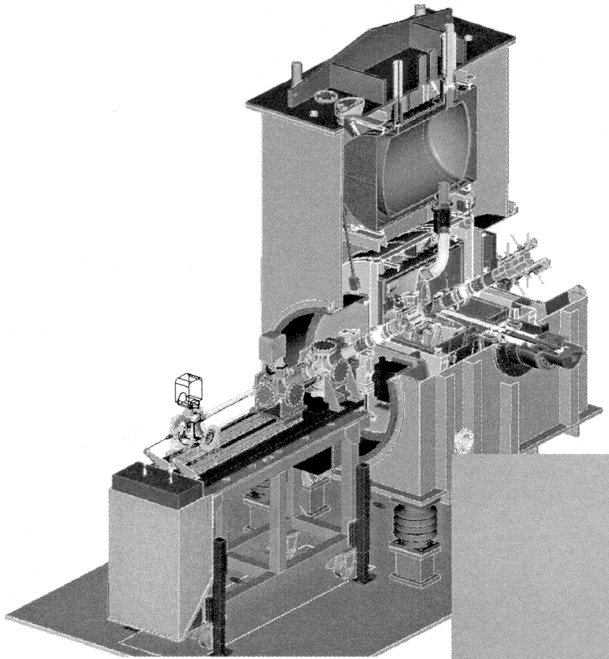


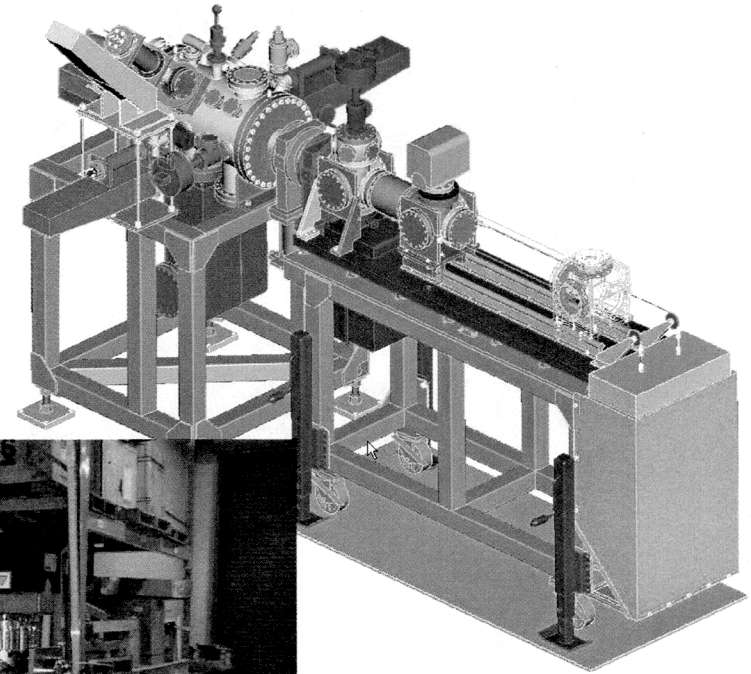
5% in green, at high current density (doubled YAG)
QE at 355 nm is 19%!

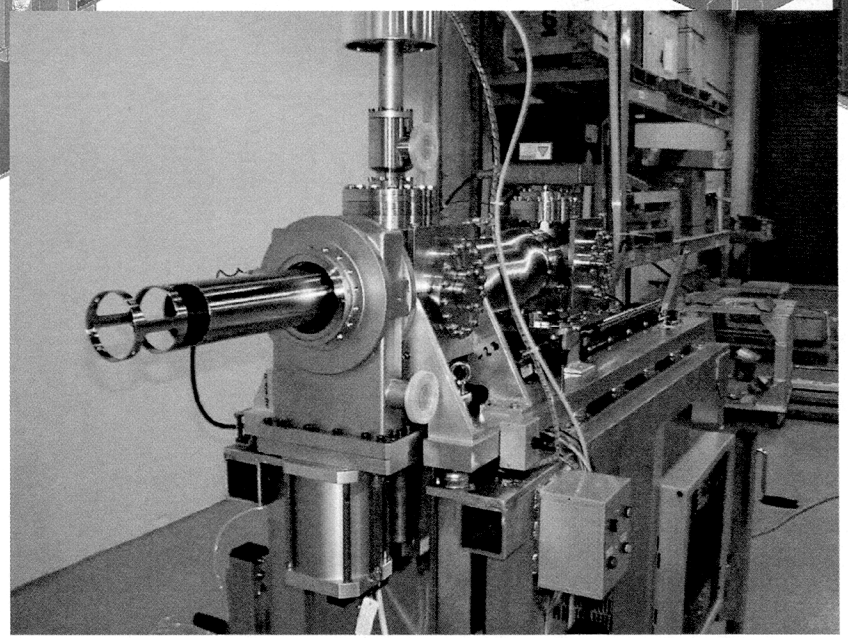
Load-lock preparation chamber



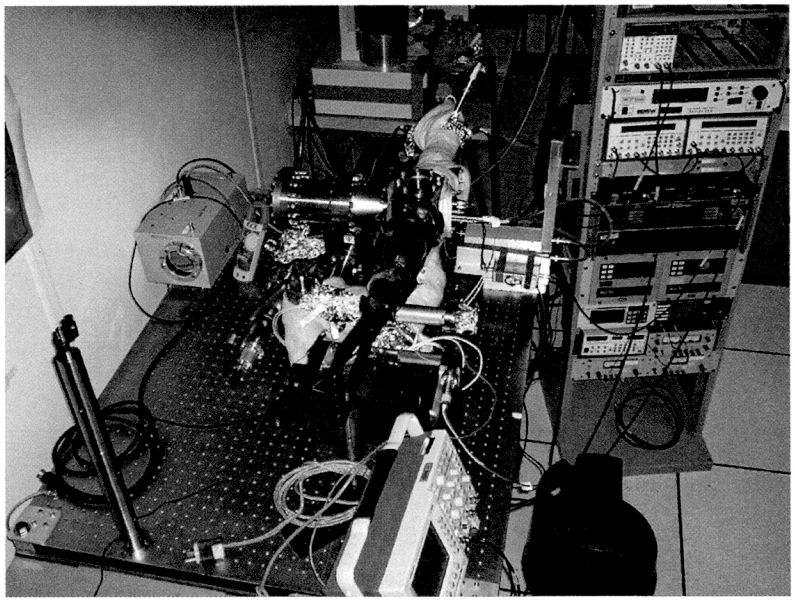
Cathode transport cart





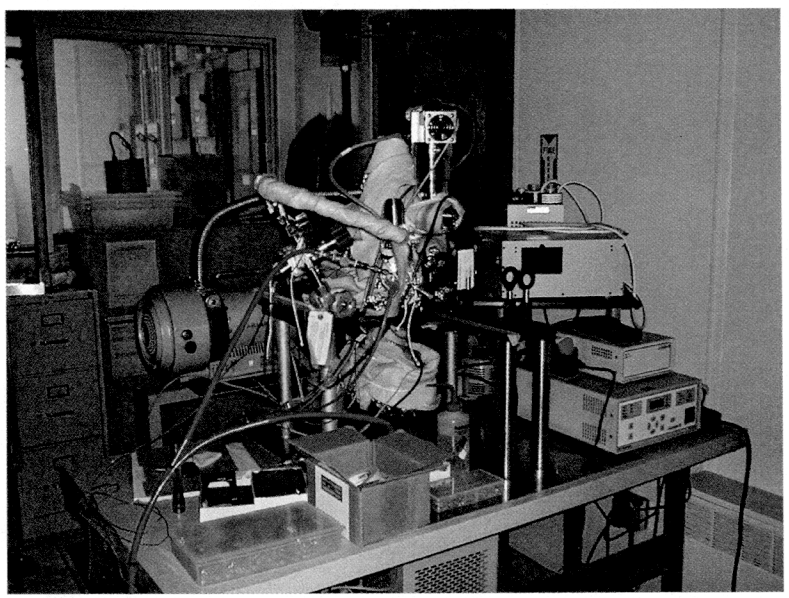


Diamond Amplified Photocathode R&D



Transmission and emission test station

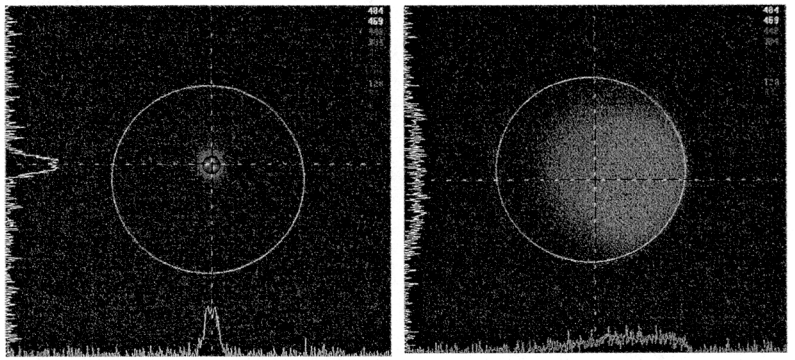
Hydrogenation station



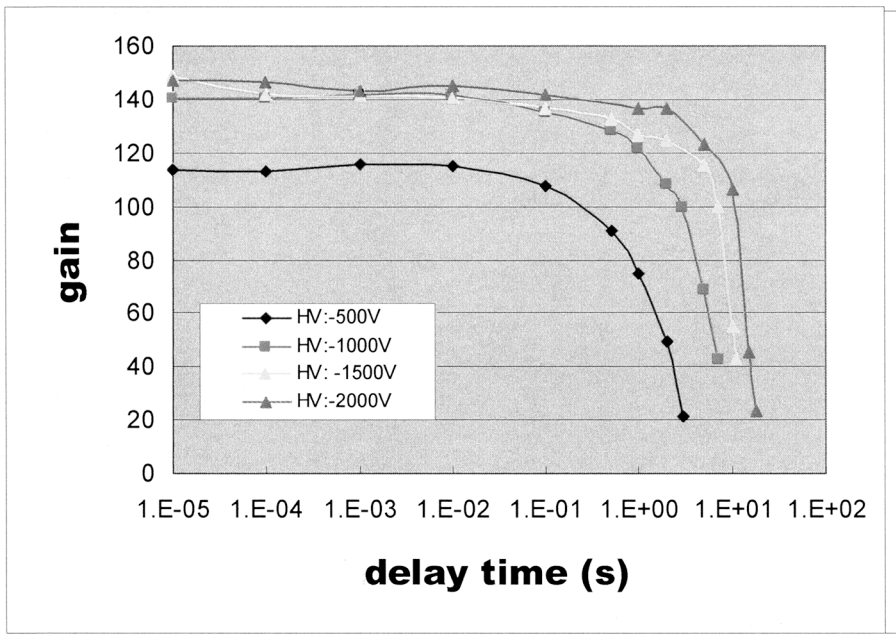
Diamond amplified cathode R&D

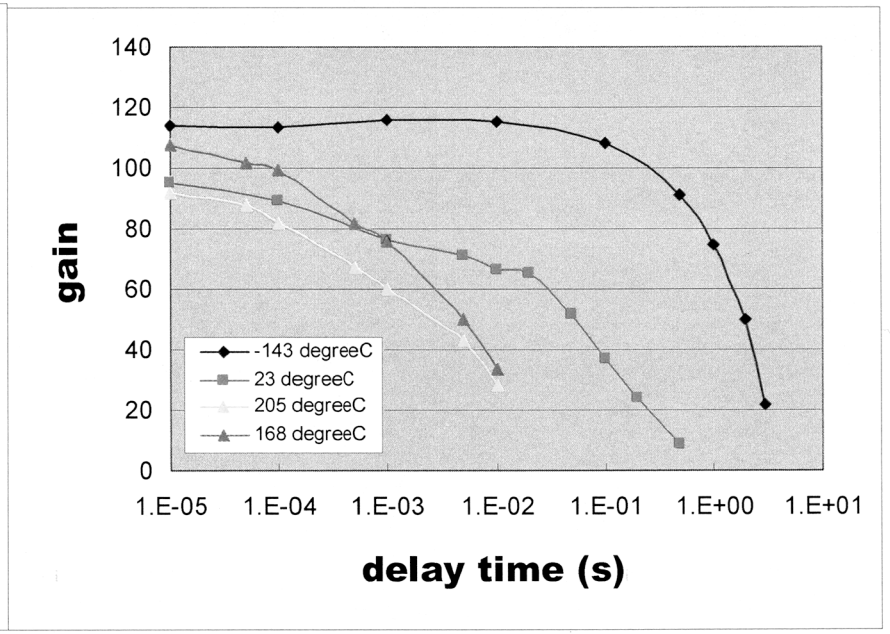
Great progress in R&D on revolutionary cathode:

- Observed large gain in emission into vacuum
- Average current density, 15 mA/mm^2 ,sub ns pulses
- Generated focused beam out of diamond
- (not simultaneously in the same test)

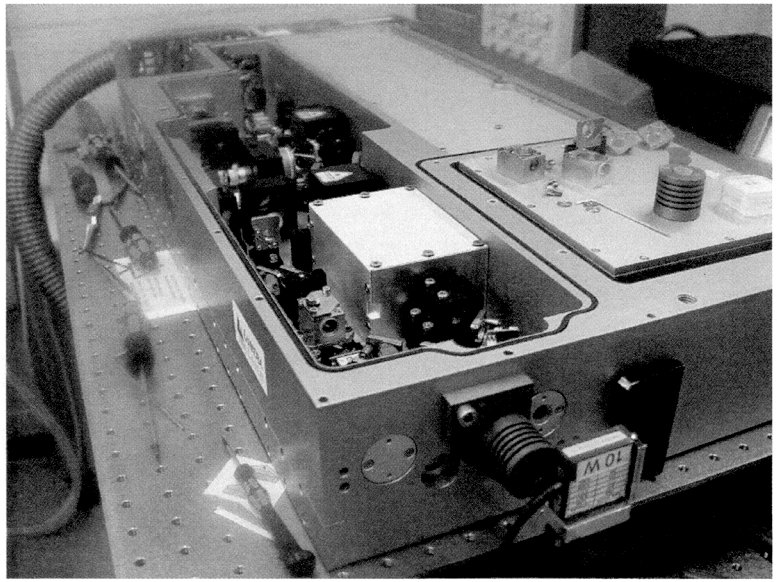


Focused and unfocused beam

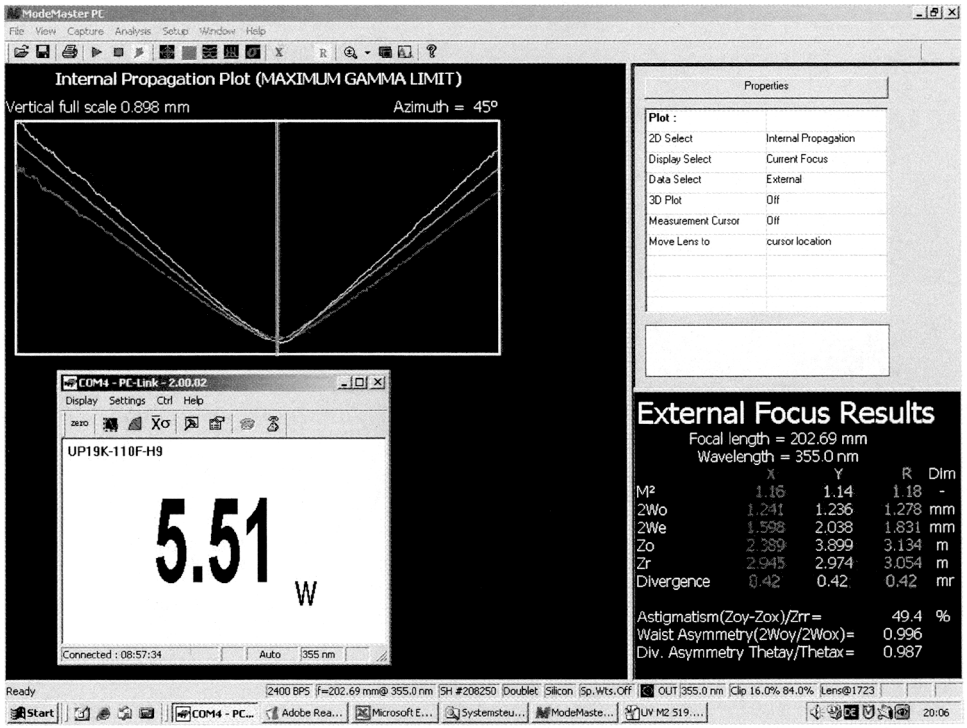




Photocathode laser constructed



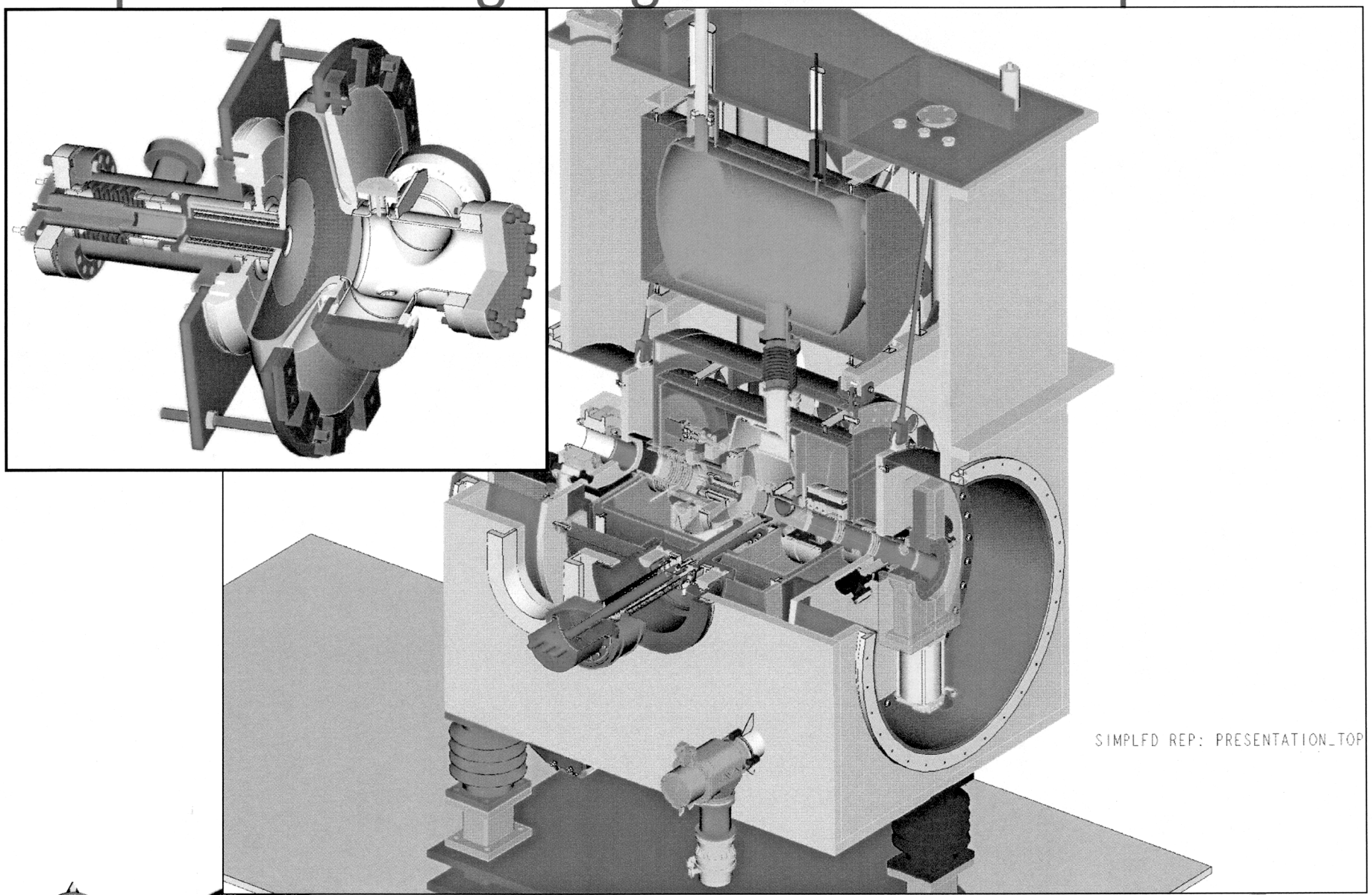
LUMERA LASER GmbH, Germany
RPMC Laser Inc, USA.
9.4 MHz rep rate
Nd:YVO_4 ps MOPA with THG 355 nm



End-pumped oscillator
Fiber-coupled
Very rigid with
no tuning elements
800 μm pump diam.

Ultra-stable amplifier

Superconducting RF gun under development.



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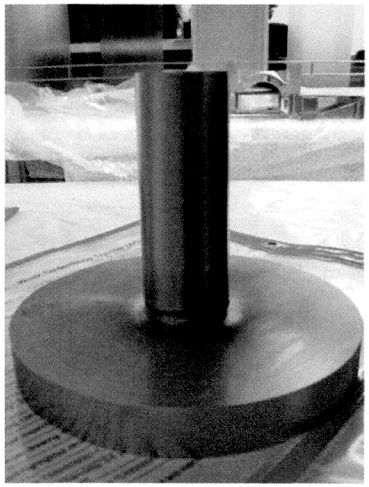
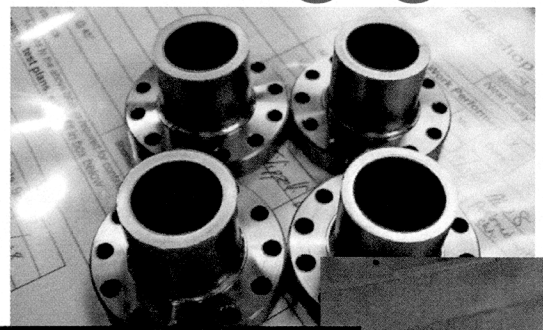
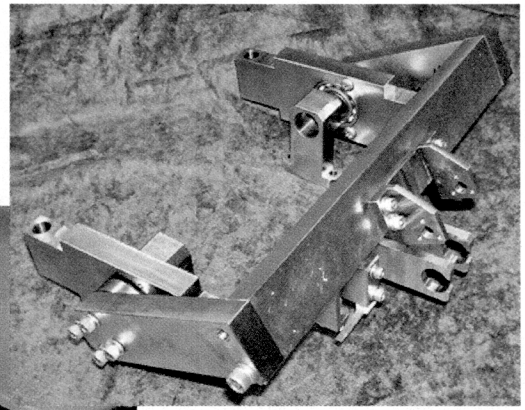
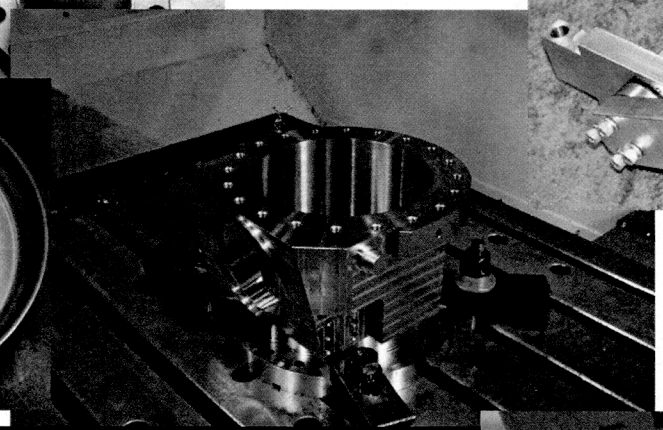
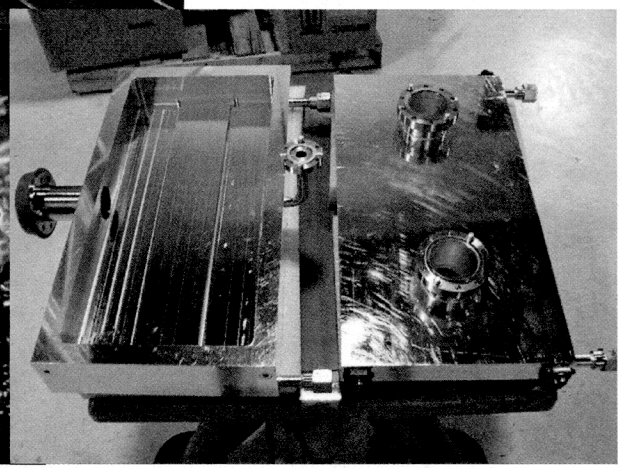
Cutting gun metal



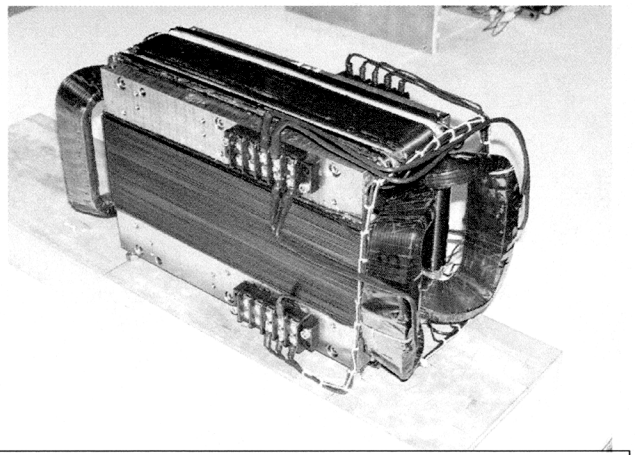


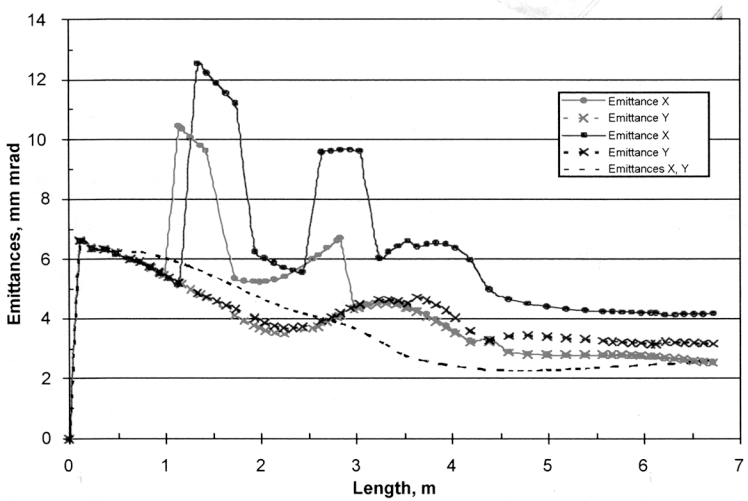


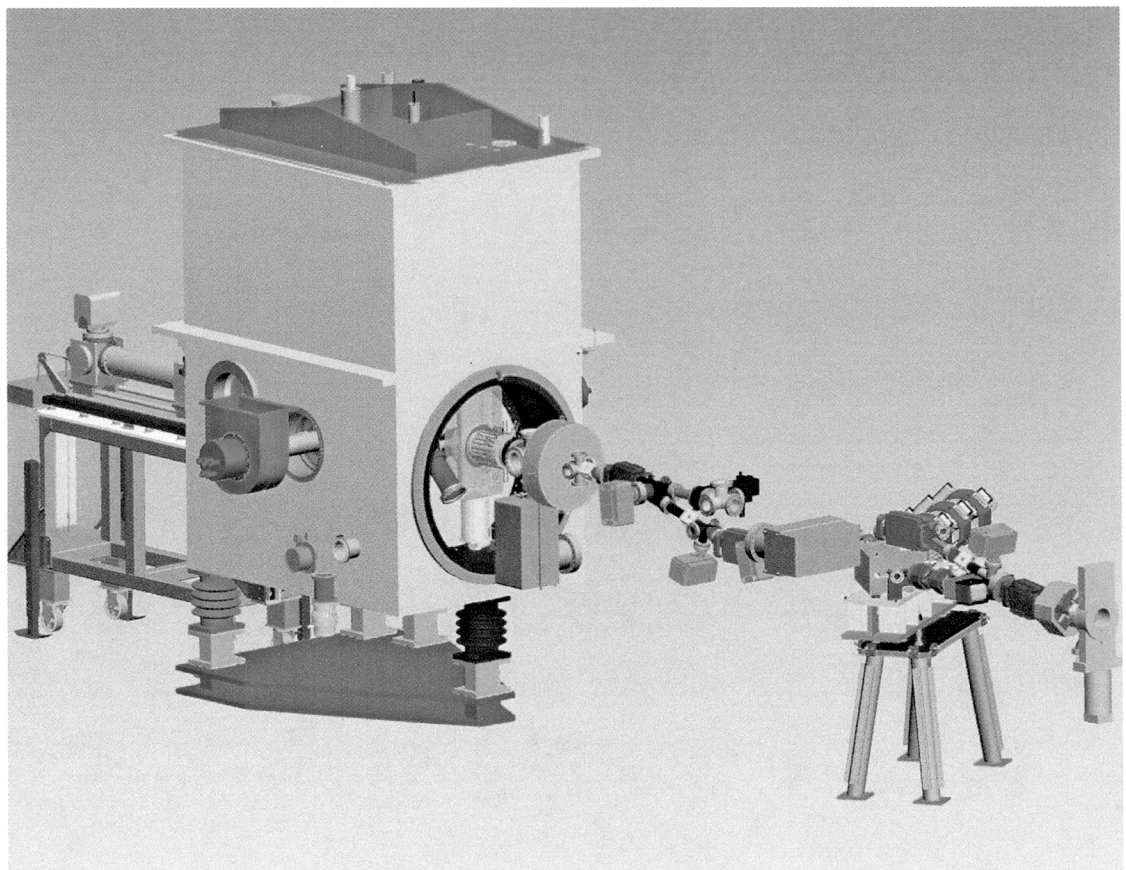




BNL's "Z-Bend" beam merger

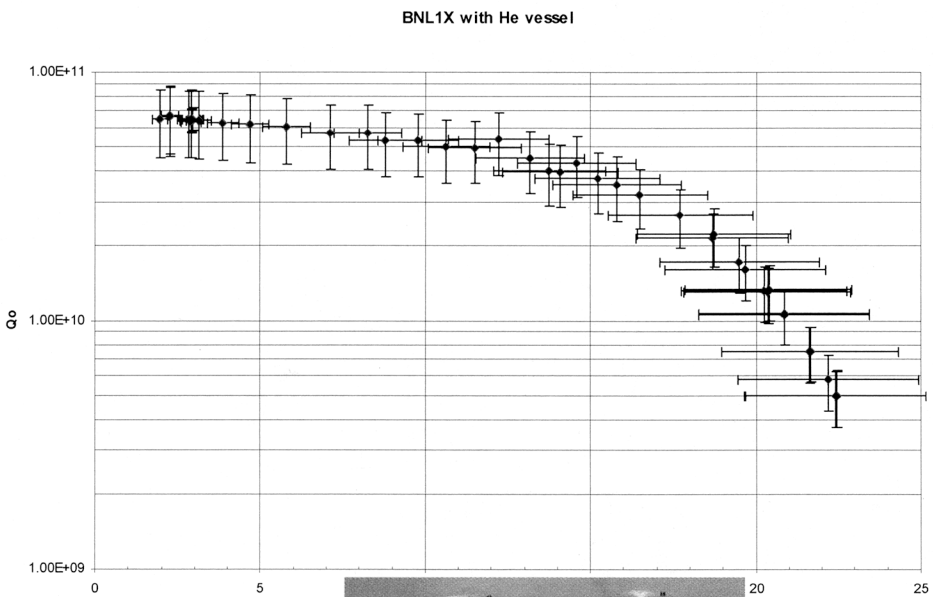


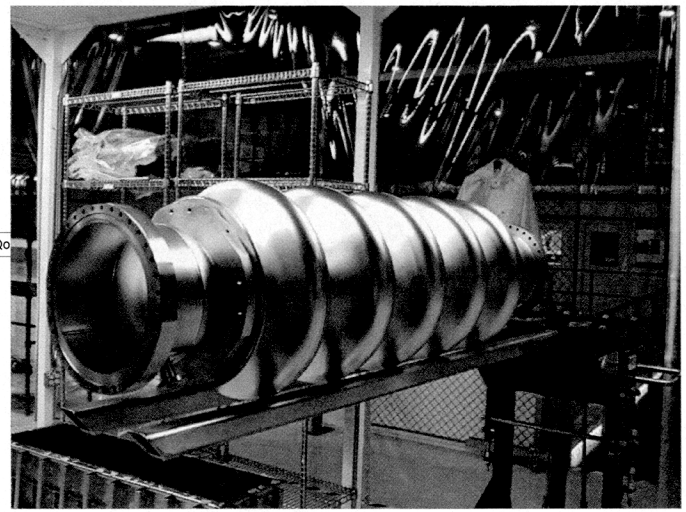


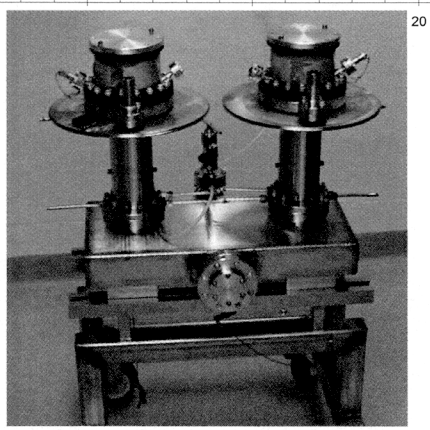


This scheme overcomes emittance blowup in the injection / merger

Cavity tested successfully



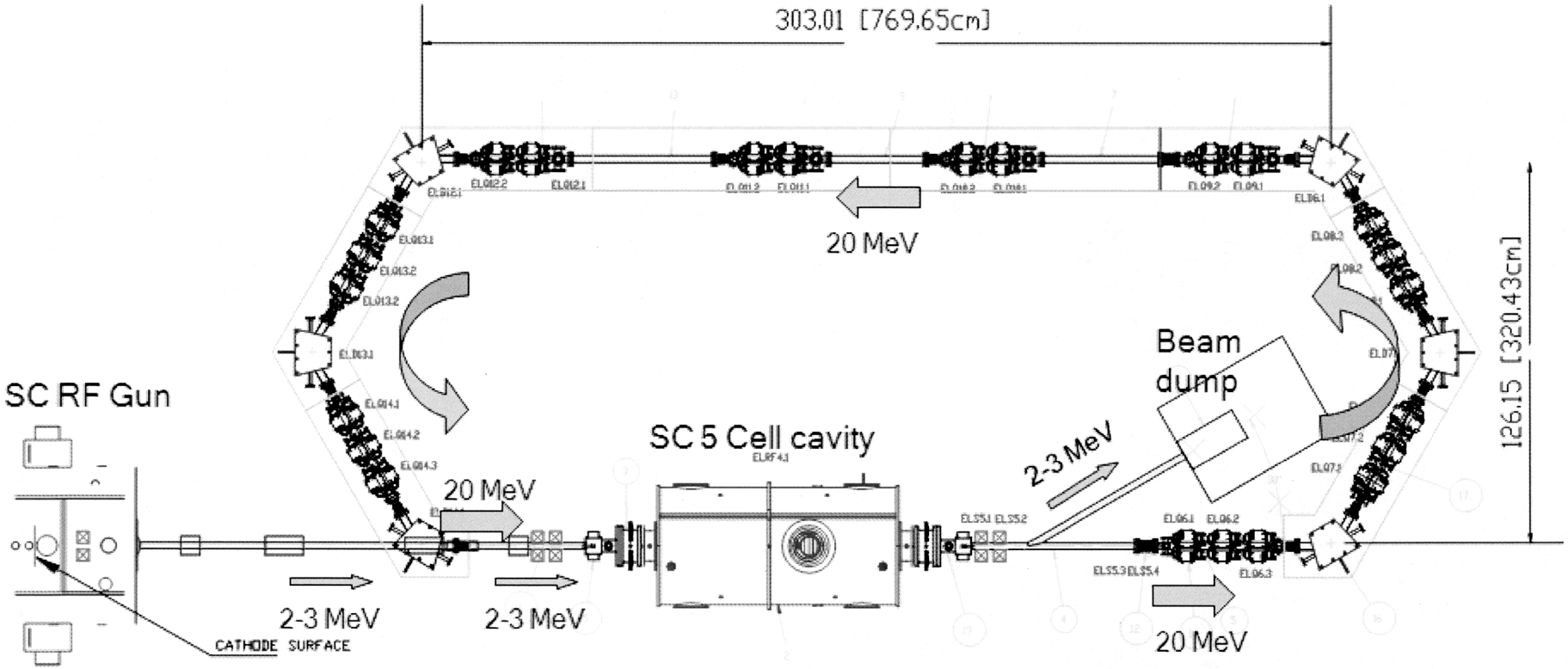




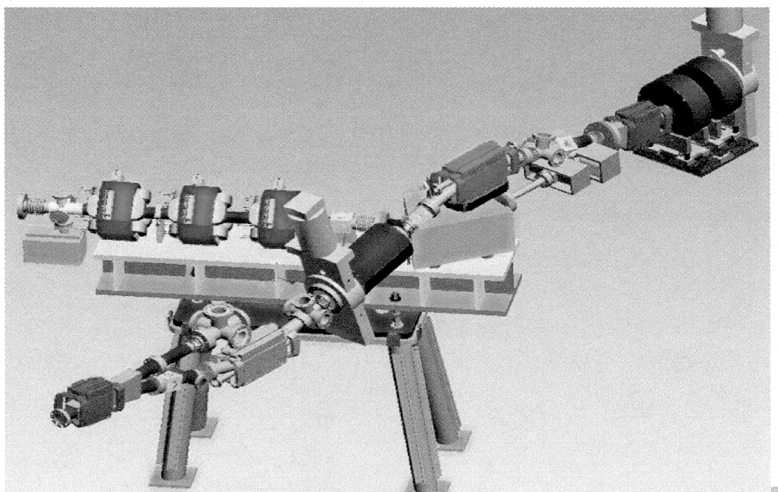
Fundamental power couplers conditioned

The Energy Recovery Linac

- The high-current SRF gun and 5-cell accelerating cavity are being fitted into a complete, small ERL.
- This is the only way possible to test the performance of all components and ERL system.
- High-precision magnets, vacuum system and diagnostics were added to form an ERL.

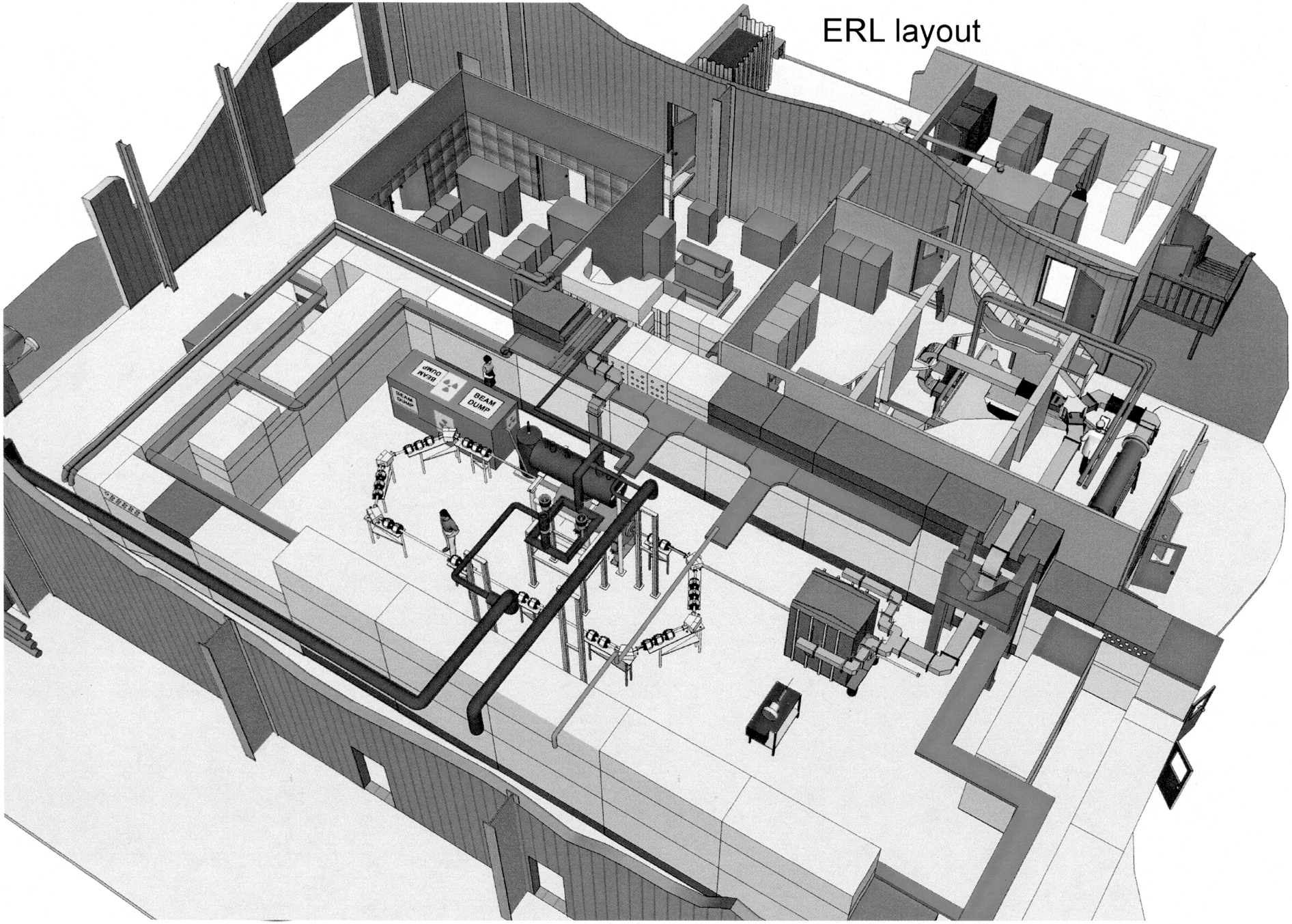


Schematic layout of the ERL (above) and 3-D detail of the injection bends (right)

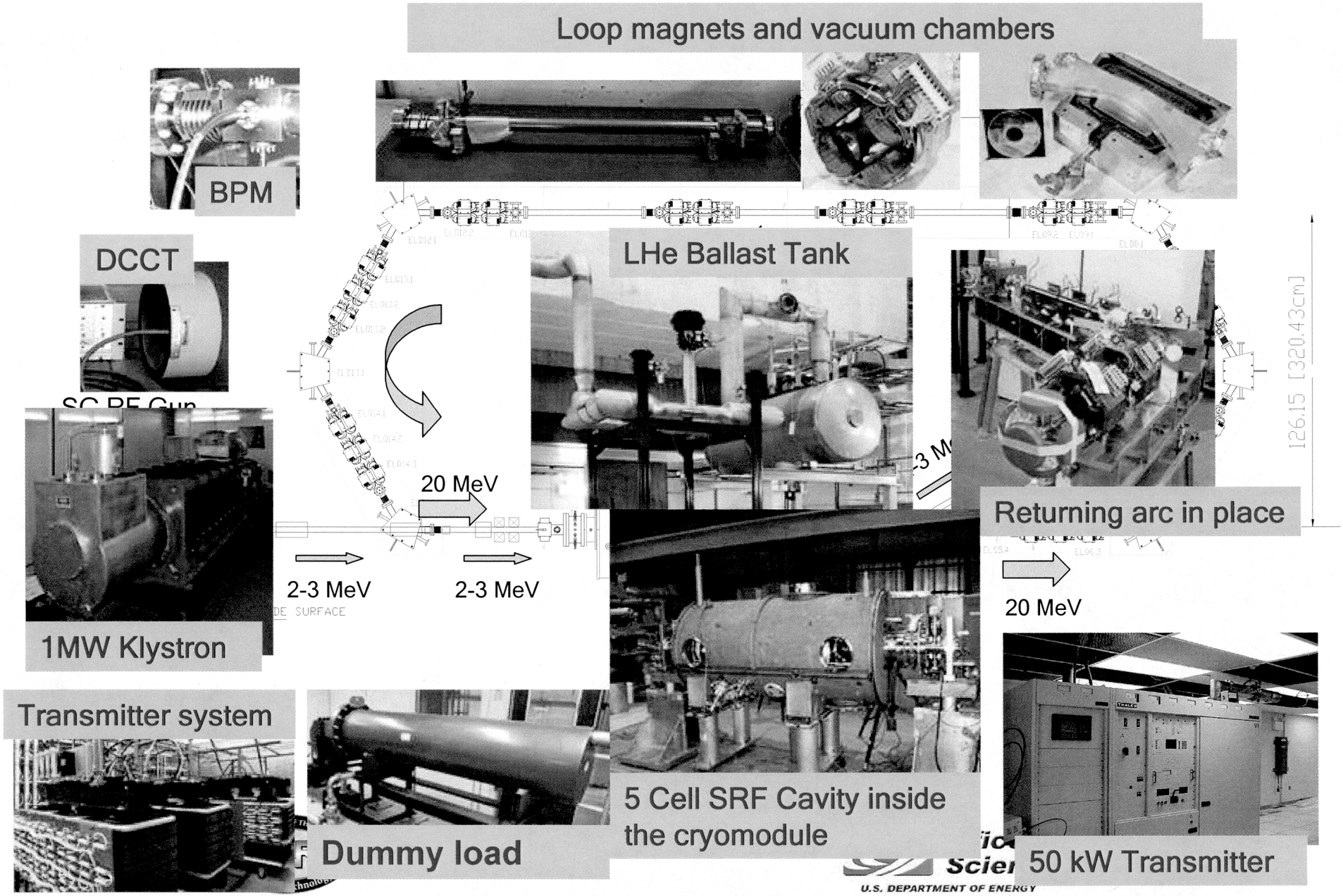


R&D ERL beam parameters

Parameter \ Operation regime	High Current	High Current	High charge
Charge per bunch, nC	0.7	1.4	5
Numbers of passes	1	1	1
Energy maximum/injection, MeV	20/2.5	20/2.5	20/3.0
Bunch rep-rate, MHz	700	350	9.383
Average current, mA	500	500	50
Injected/ejected beam power, MW	1.0	1.0	0.15
R.m.s. Normalized emittances ex/ey, mm*mrad	1.4/1.4	2.2/2.3	4.8/5.3
R.m.s. Energy spread, $\delta E/E$	3.5×10^{-3}	5×10^{-3}	1×10^{-2}
R.m.s. Bunch length, ps	18	21	31


ERL layout
BEAM DUMP
BEAM DUMP
BEAM DUMP

R&D ERL: To be completed 2010



BNL R&D ERL: Status

- ERL Enclosure (Vault) was constructed
- Gun is under construction at AES
- 5-cell Cavity is being processed and tested at JLAB
- Horizontal test 5-cell cavity in cryostat at BNL in December 2008
- 1 MW Gun klystron and 50 kW 5-cell cavity transmitter are installed, tested.
- Loop magnets manufactured and had magnetic measurements
- Recirculation loop vacuum system components are ready for installation
- Gun drive laser has been procured, will arrive in November 2008
- RF control will be based on the new digital RHIC LLRF.
- Machine protection system is being designed (BLMs, DCCTs)

We start commissioning the R&D ERL in 2009

1) Straight pass (gun -> 20 MeV 5 cell cavity -> beam diagnostic) test.
2) Test concept of emittance preservation in a beam merger
3) Demonstrate energy recovery with high bunch-charge / beam current
4) Study beam and stability issues relevant for high current ERLs