Push-Pull FEL
A New ERL Concept

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Drivers for a New Concept

- The ILC will use superconducting technology
  - Many components of the X-FEL at DESY are similar
- Most components of a superconducting accelerator are being, or will be, industrialized for the ILC and the X-FEL
  - Cryomodules
  - Injector
  - RF power sources

Concept - design an FEL based on "cheap" ILC components

- Modifies the design of the electron optics in favor of:
  - more cryomodules
  - more injectors
  - less beam transport

New Concept - Electrons

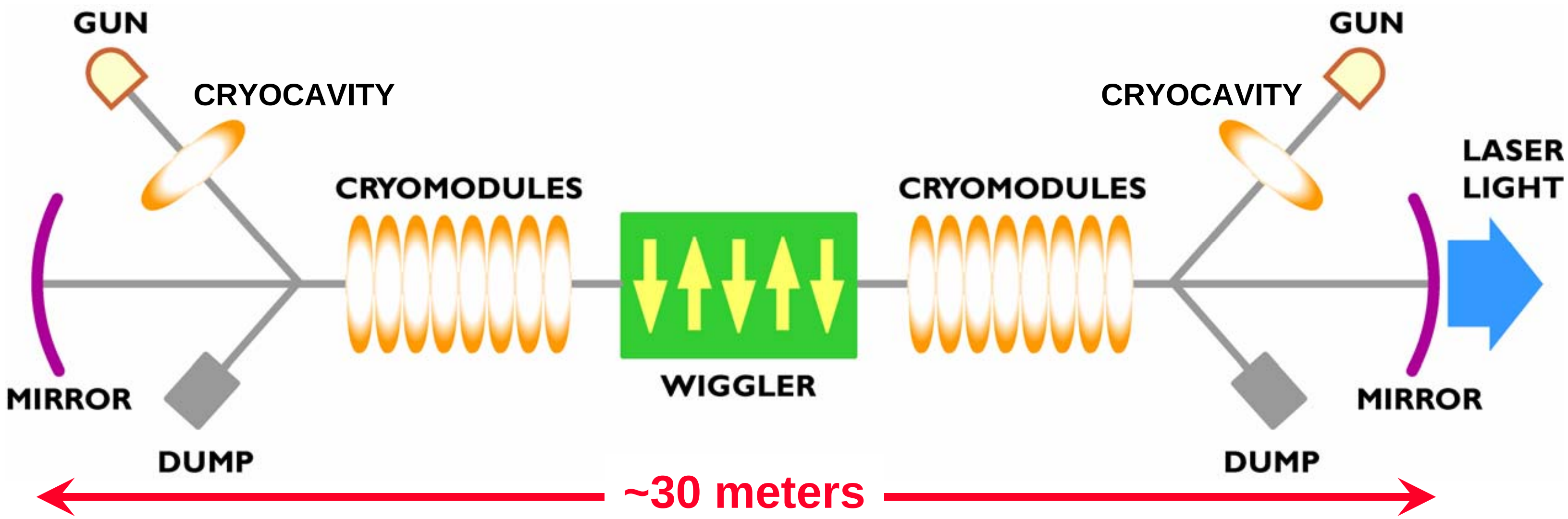
- New concept uses two sets of superconducting cavities with two identical electron beams going in opposite directions
- Each set of superconducting cavities accelerates one electron beam and decelerates the other beam
  - The energy used to accelerate one beam is recovered and used for the other beam
- The difference between this proposal and other energy-recovery proposals is:
  - Each electron beam is accelerated by one structure and decelerated by another
  - This is energy exchange rather than energy recovery

Concept - Light

- A further simplification can occur if the superconducting cavities produce sufficient energy
- The superconducting cavities can be contained within the optical resonator with the light pulses traversing them
- This arrangement leads to an extremely compact layout suitable for a university laboratory

Operated by the Southeastern Universities Research Association for the U.S. Department of Energy

Conceptual Layout



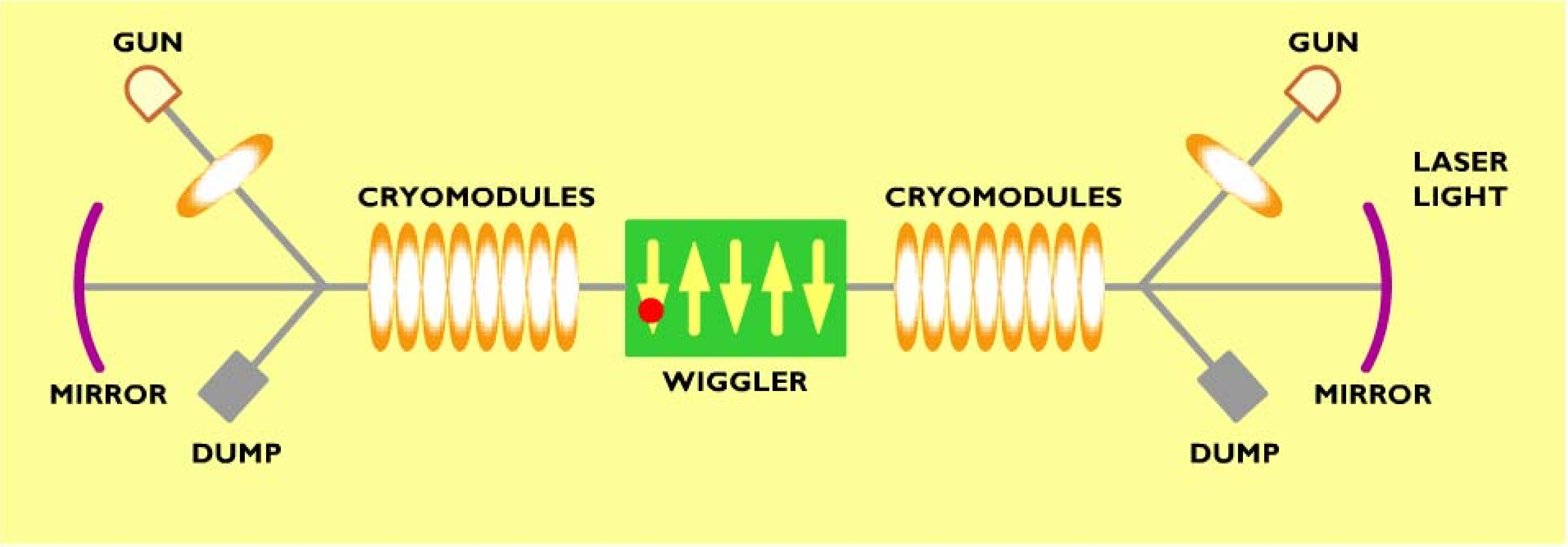
The two cryomodules containing the superconducting cavities flank a wiggler that is used to produce coherent light

The addition of a pair of mirrors outboard of the cryomodules completes the free Electron Laser (FEL) optical cavity

On either end, there is a 10 MeV injector (gun + cryocavity) that can either be a copy of that used at the Jefferson Lab FEL or (better) an SRF gun

The electron beams are brought onto the acceleration axis by a separator magnet, which also serves to bend the spent beam to a dump

Illustration of the Concept



Animation by Tom Oren

Energy Balance

- RF energy in the cryomodules is recovered completely
- RF energy given to the beam by the injector is partially converted to FEL light and partially dissipated in the dump
  - The bend magnet needs to be carefully designed to transport electrons with a large (~50%) energy spread to the dump with extremely small losses
  - Better alternative is to do energy compression

- So the maximum FEL power that can be extracted is some fraction (up to about 50%) of the power in the injector

Parameter Set

- An example of a parameter set has been calculated
  - Compared to design parameters of 10 kW JLab FEL
  - Design power output has been achieved, so parameters are within the state of the art
- The superconducting cavities are based on DESY X-FEL prototypes
  - Cryomodule contains eight 9-cell superconducting cavities operating at 23 MV/m for a total of 190 MV
  - The superconducting cavity in the injector is one of the same cavities operating at less than 10 MV/m.
    - Injection energy should be less than ~10 MV to avoid neutron activation of the dump.

Parameter Example

Parameter	10 kW JLab FEL Design	Push-Pull FEL Design
Maximum Beam Energy	80 – 210 MeV	200 MeV
Injector Beam Energy	10 MeV	10 MeV
Beam Current	10 mA	2 x 0.5 mA
Beam Power	800 – 2100 kW	2 x 100 kW
Non-Recovered Beam Power	100 kW	2 x 5 kW
RF Frequency	1500 MHz	1300 MHz
FEL Repetition Rate	3.9 – 125 MHz RF Frequency/(4 – 384)	5.078 MHz RF Frequency/256
Optical Cavity Length	32 meter	29.539 meter
Bunch Charge	135 pC @ 75 MHz	100 pC
Energy Spread after Wiggler	10% of 210 MeV	2.5% of 200 MeV
Energy Spread at Dump	~2% of 10 MeV	50% of 10 MeV
FEL Output Power	10 kW	> 1 kW

Other Hardware

- RF Power source
  - The klystron being developed at Cornell for the ERL Light Source would be perfect for this application
    - Enough power for both injectors and both cryomodules
- RF Distribution and Low-Level RF control
  - The RF power distribution system and LLRF control adopted for ILC is perfect for this application
- Focusing
  - A quadrupole doublet at each Injector, a quadrupole doublet each side of the wiggler, and a quadrupole in the center of the cryomodules (as in the present X-FEL cryomodules) provide sufficient flexibility

Outstanding Questions

- Drive laser rep rate (5 MHz) is not easy
  - Lasers like high rep rate or low rep rate
  - A few MHz is currently difficult
  - The most stable solution uses a single drive laser with a splitter providing light to both guns
    - Needs precisely calibrated optical delay
    - Avoids problem of precisely synchronizing two separate lasers
  - Drive laser needs real work

- Complete a detailed design
  - No obvious problem areas other than the laser
  - Integrate bunch compression/energy compression

Summary

A new ERL concept is proposed

- Small footprint and few tunable parameters
  - Optimal for a university laboratory setting
- Uses components being developed for the ILC
  - Should become cheap and reliable

Design studies will continue

Awaiting a User with deep pockets!

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