Working Group D Summary

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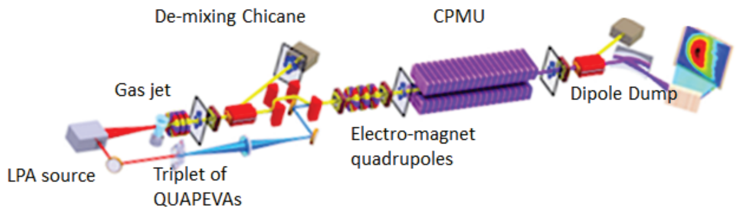
Shanghai, March 9, 2018

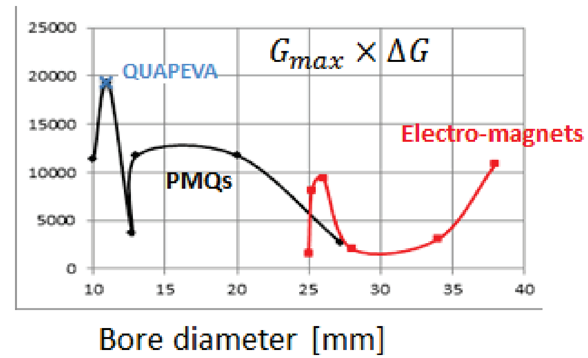
Focus 1: Magnet & Undulator Technology

- Small Variable High Gradient Magnets (Amin Ghaith)
- Design Studies of the High Gradient Magnets for a future Upgrade of MAX-IV (A. Vorozhtsov): (Big Accelerator Magnets, optimization of space, compactness and operation cost)
- Cryogenic undulator, (M. Valleau)
- Superconducting Undulators (N. Fuerst, J. Clarke (2)
- Trajectory analysis in undulators (H. Jeevakhan)
- Partial coherence of spontaneous undulator radiation (M. Sanchez del Rio)

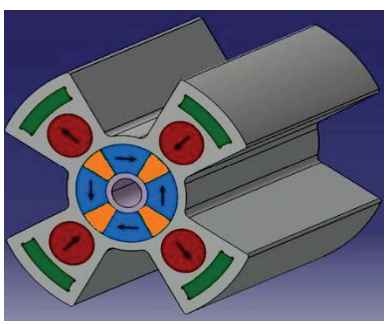
Small PM Quadrupoles for use in Plasma & Wakefield ACCs

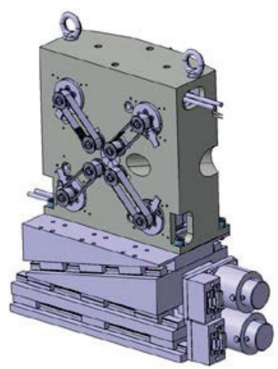
Amin Ghaith: QUAPEVA **QUA**drupole **PE**rmanent magnet based with **VA**riable gradient





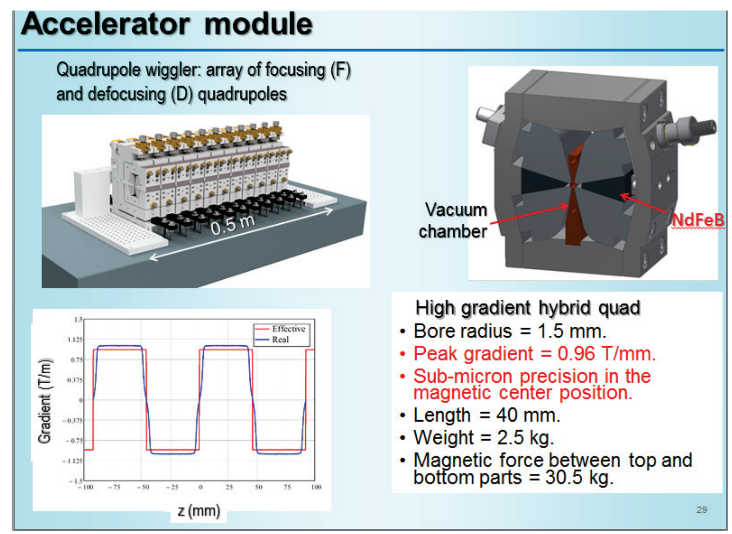
- Trend/Need for Miniaturization → small aperture, gaps, short magnetic Lengths < ≈ 20 mm
- **PM Regime:** Small Dimensions High Fields (K. Halbach 1980)
- PM Quadrupoles with Gradients >500T/m @ (and 6mm aperture) are possible



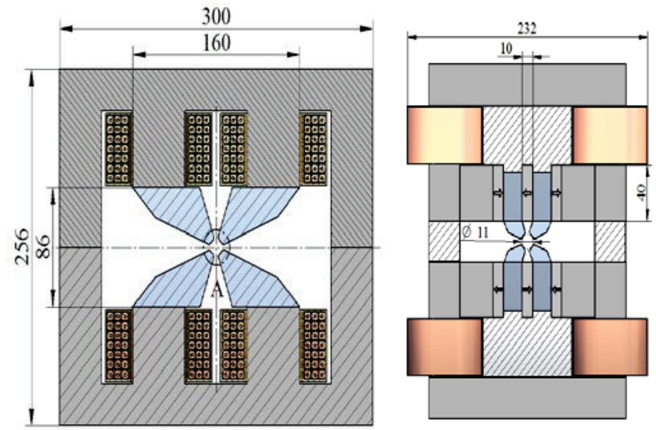


Example: Adjustable PM Quadrupole for COXINEL Project; L=23/50mm; G<≈200T/m; ∅≈10mm

John Power: Concept for a Wakefield Accelerator



QFE Magnet design

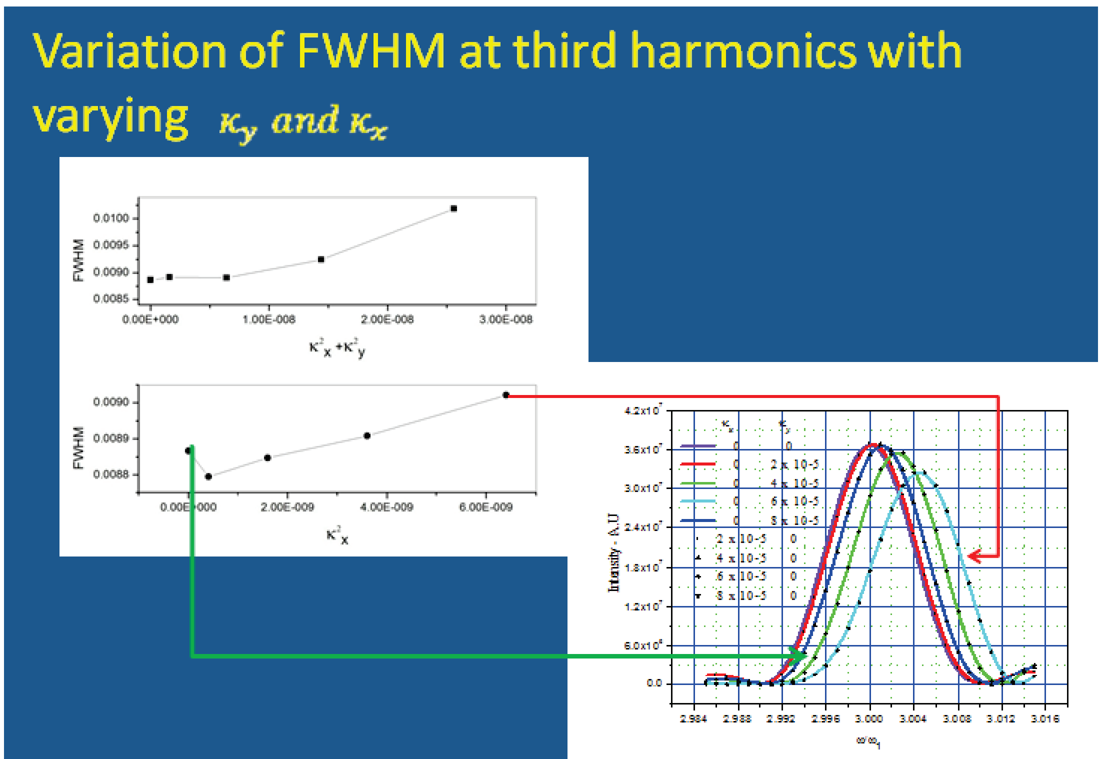


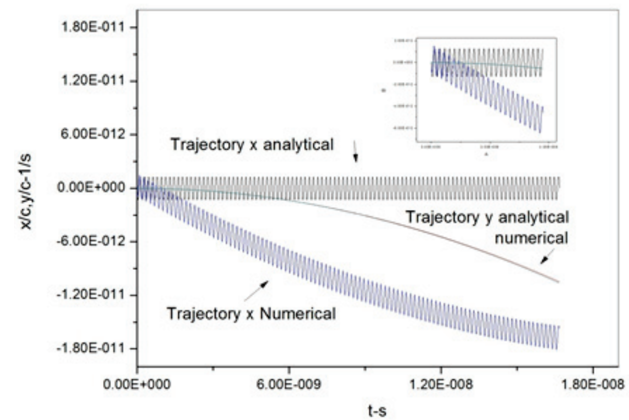
Magnet type	Pros	Cons
Pure electromagnet	• Less complicated manufacturing / assembly	• Large power consumption (running cost) • Vibration induced by the water cooling
Hybrid magnet	• Low power consumption • Compact solution ?	• Assembly difficulties (magnetic forces) assuming the magnet block concept • Large capital cost (permanent magnet material)

WEA2WD03_04 Hussain Jeevakhan:

Analysis of electron trajectories with SCILAB

Undulator Radiation with dual non-periodic Field Components





Cryogenic undulators

M. Valleau, THP2WD01: Construction and optimization of cryogenic undulators at SOLEIL

The art of building highest quality cryogenic undulators: PrFeB Material, Br 16% hight than at RT
Low Phase- & Trajectory Errors, Precision Manufacturing avoid shimming, in-situ measurements
Errors, Thermal effects corrected,

After assembly of the undulator:

U18 n^o1

- Taper correction
- Rods adjustments
- 92 elements shimmed

↪ Phase error : 2.8 ^{o}

U18 n^o2

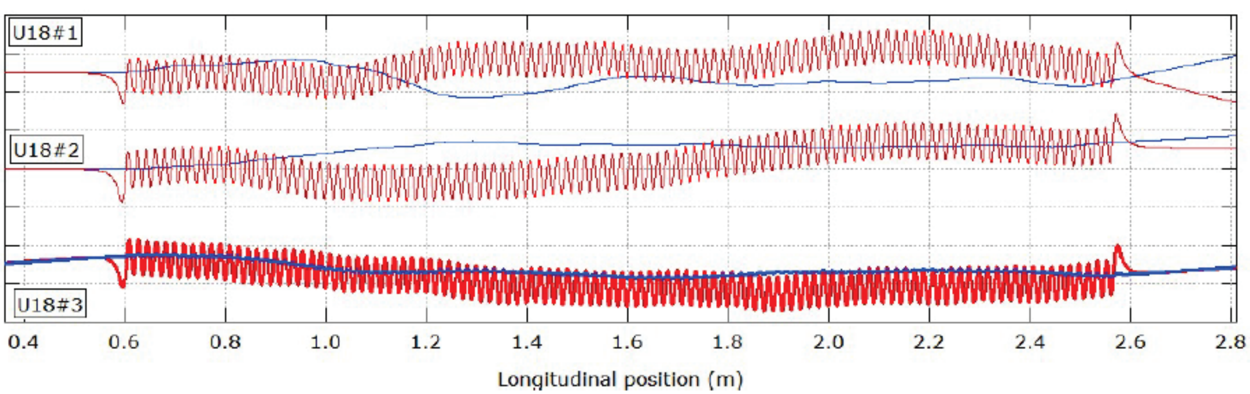
- Taper correction
- Rods adjustments

↪ Phase error : 2.3 ^{o}

U18 n^o3

- Taper correction
- Rods adjustments

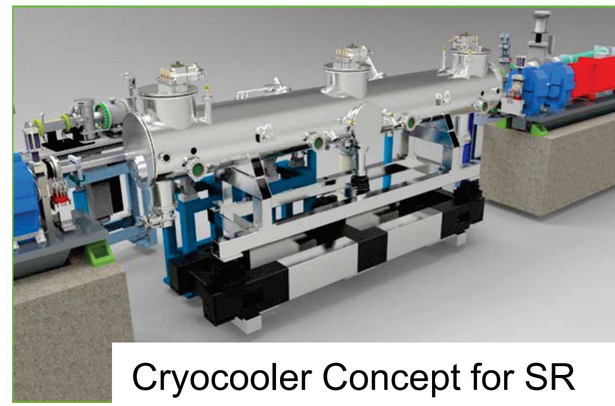
↪ Phase error : 2.45 ^{o}

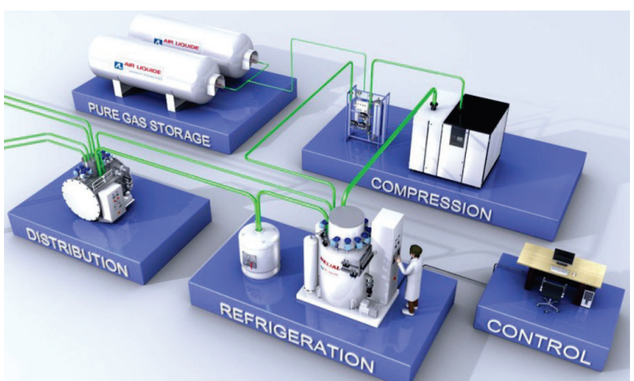


Superconducting Undulators

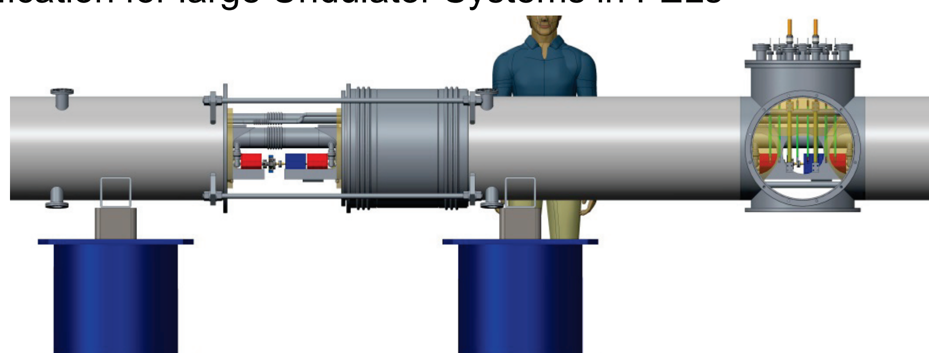
Noel Fuerst, ANL MOA2PL03 : Review of new developments in superconducting undulator technology at the APS

- Planar SC undulators L ≈ 2m, Working on Nb_3Sn technology
- Single Helicity Circular polarizing undulator L=1.2m
- Super Conducting Arbitrarily Polarizing Emitter (SCAPE) Undulator in development
- Better cryostat for use in Storage Ring using cryocoolera
- Plans for Undulator Systems in FELs with Helium liquifications for large systems
- Integration of Undulators, Phase Shifters, Quads, BPMs….

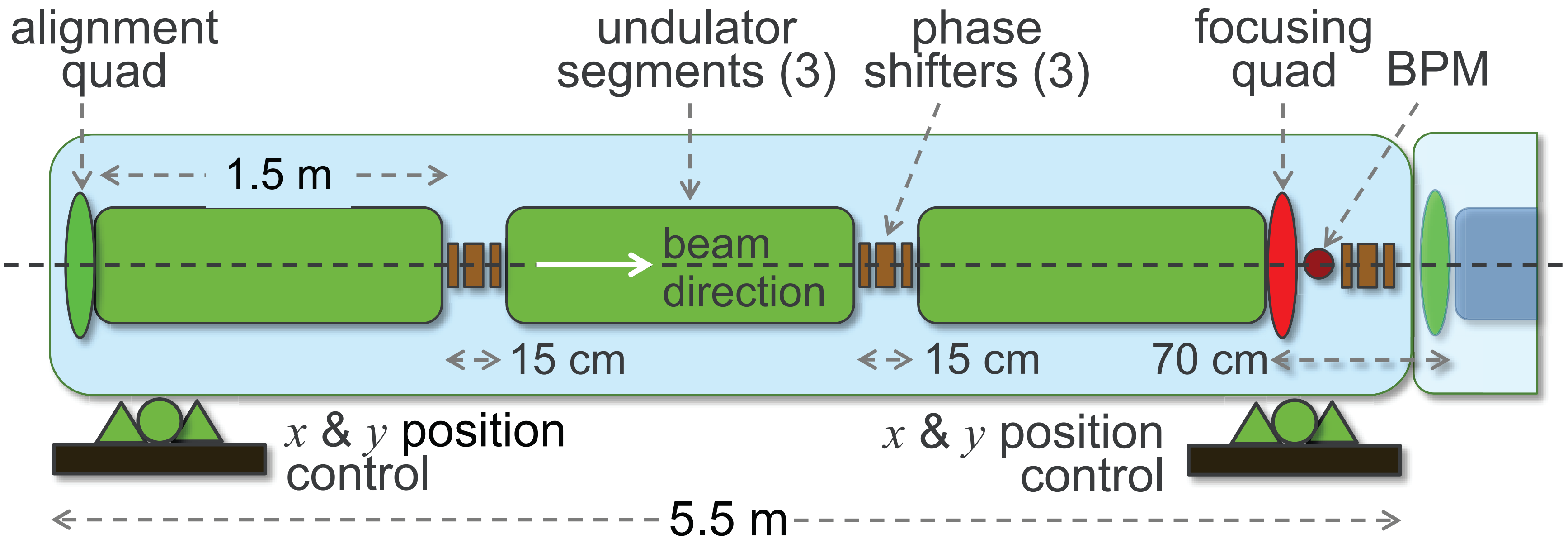

Cryocooler Concept for SR



Liquification for large Undulator Systems in FELs



FEL SCU CRYOMODULE CONCEPT (P. Emma, SLAC + ANL/LBNL)



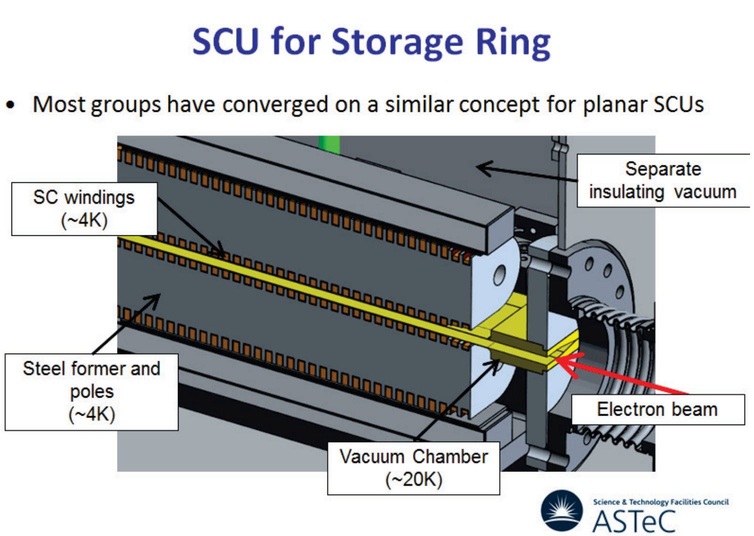
- Three 1.5-m long undulator segments in one 5.5-m cryostat
- Short segments (1.5-m) easier to fabricate, measure, tune, and taper
- Each segment independently powered to allow optimized TW-taper
- Ancillary components include cold BPM, cold phase-shifters, cold quads
- Cryogenic refrigeration/distribution system concept has been developed
- Magnet alignment is critical (300 K →4 K)
- Beam-based alignment as final correction using motorized pads

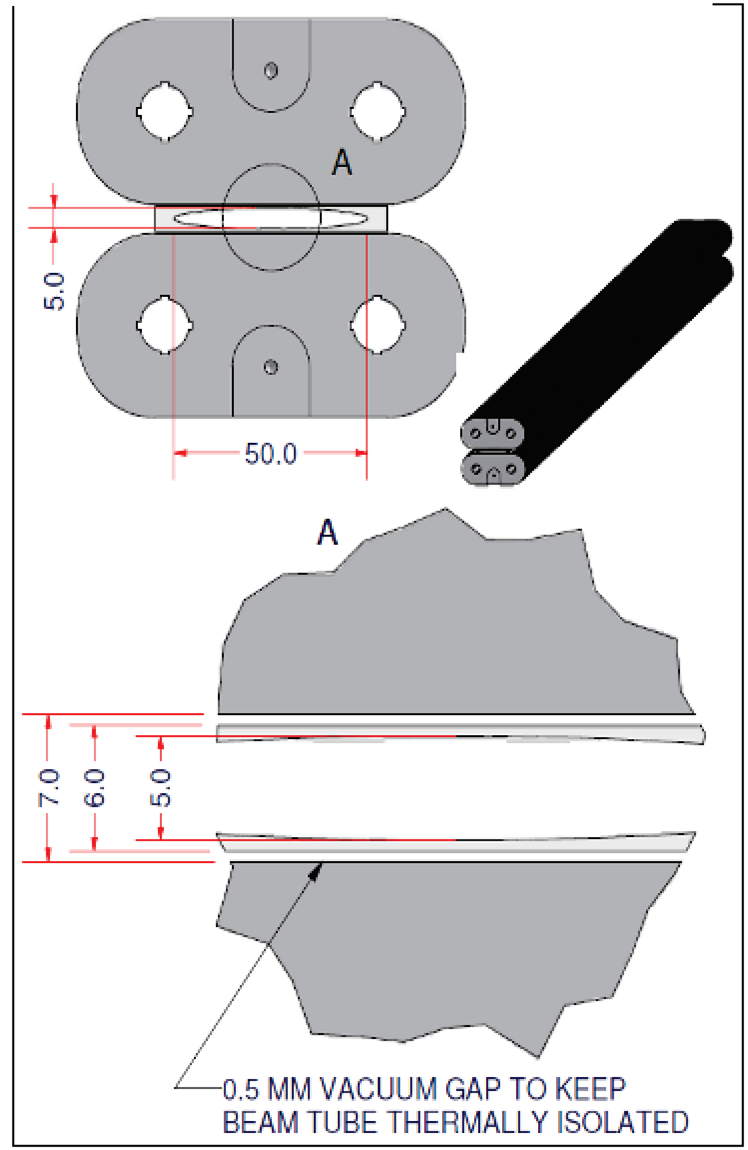
- On the way towards SC Systems in XFELs
- Commercialization???

Argonne NATIONAL LABORATORY

Magnet Gap

- Standard SCU Example:
  - Beam stay clear = 5.0mm
  - Vacuum chamber wall thickness = 2 x 0.5mm
  - Insulating gap between 20K vac chamber and 4K magnet = 2 x 0.5mm
  - **Magnet aperture = 7.0mm**





Manuel Sanchez del Rio, THP2WD03,
Partial coherence in undulator beamlines at ultra-low emittance storage rings

Accurate coherent mode decomposition and analysis of undulator radiation for ESRF and ESRF upgrade

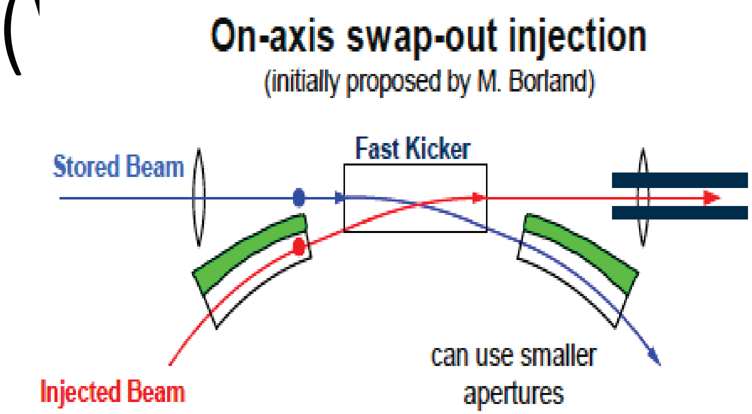
For storage rings emission all coherence properties can be deduced from the Cross Spectral Density. Its storage and propagation is usually unmanagleable by present computers
Provides a method of storage of Cross Spectral Density

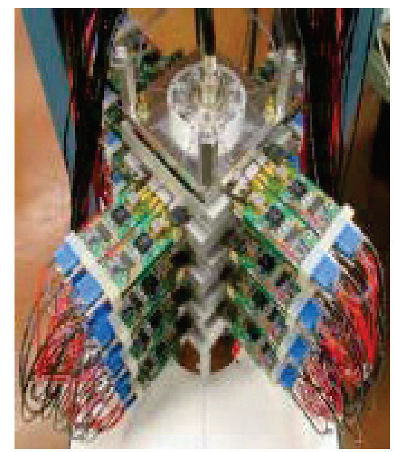
Focus 2: Accelerator Technology

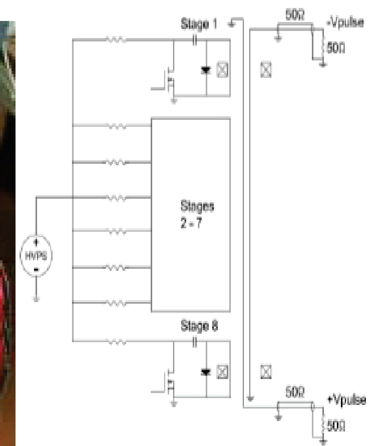
- Fast kickers and pulsers for swap-out/in injection for ALS-U
  - Will Waldron, Berkeley Lab
- High Power Solid-State RF Systems for Storage Rings
  - Jorn Jacob, ESRF
- RF System for Siam Photon Source 2
  - Nawin Juntong, SLRI
- CW High Brightness Photocathode Guns
  - Feng Zhou, SLAC
- Beam Containment Systems for 250 kW Class Electron Linac (LCLS-II)
  - Christine Clarke, SLAC
- New photocathode gun at the APS linac towards a new accelerator R&D facility
  - Yin-e Sun, Argonne

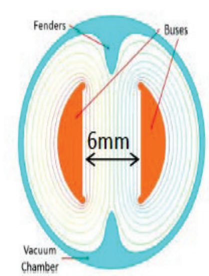
Swap-out injection kickers are close to achieving requirements (

- Ultralow emittance MBA lattices have small dynamic apertures and require on-axis “swap-out” injection where stored bunches are wholly replaced by full charge bunches. Requires fast injection kickers and pulsers that do not disturb neighboring bunches.
- Goals are <10 nsec rise and fall times.
- Solutions are:
  - Small aperture stripline kickers
  - HV pulsers (MOSFET Arrays, MOSFET-switched inductive adders, step recovery diodes and fast ionization devices, electromagnetic shocklines)
- Extensive testing in the ALS ring is close to achieving specs
  - Striplines perform well but can be deformed from beam heating under some beam conditions
  - Induction adder is preferred technology for ALS

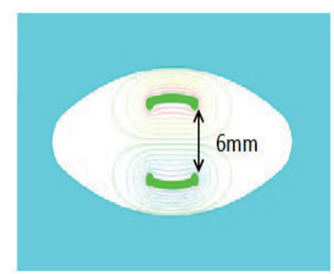








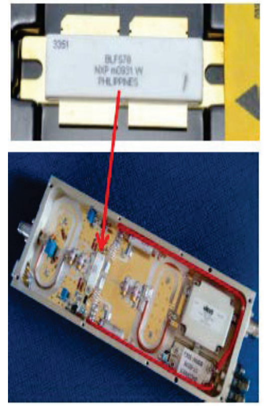
ALS-U (preliminary)



Prototype at ALS

Solid-state High Power RF systems are becoming standard in new rings (Jorn Jacob)

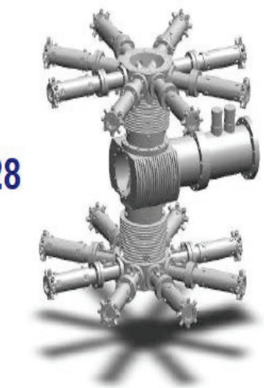
- Scarcity and increasing costs of high power klystrons are driving forces to develop solid-state power amplifiers
- Approach is to combine many low-power (0.5-2 kW) units together using either coaxial, cavity or waveguide combiner.
- Reliability is good due to modularity. Experience at Soleil/ESRF very good (1 trip of Soleil booster RF in 11 years!)
- Capital cost is higher than klystrons but maintenance costs are lower. Costs expected to drop with new commercial developments.
- Detailed pros/cons provided in talk and paper.



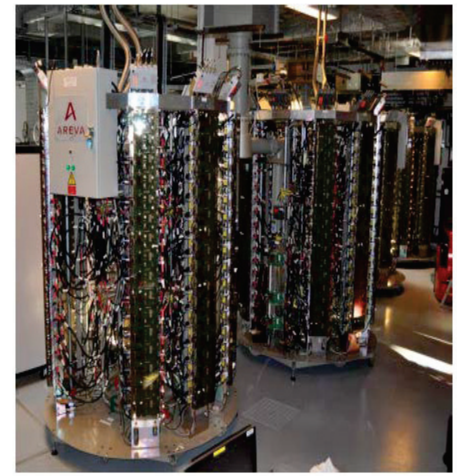
650 W RF module

➤ DC to RF: η = 68 to 70 %

x 128



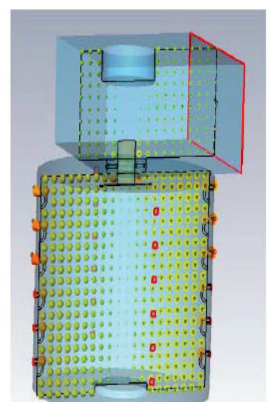
75 kW coaxial power combiner tree



150 kW - 352.2 MHz SSPA

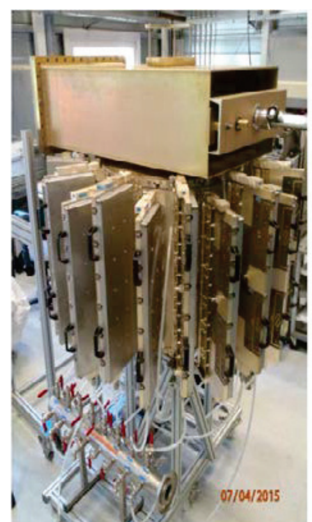
DC to RF: η > 55 % at nominal power

☛ 7 such SSAs in operation at the ESRF!



H field

Homogenous magnetic coupling of all input loops



$\eta_{RF/DC}$ = 62 % at P_{nom} = 85 kW

P_{test} = 90 kW

New Proposed Siam Photon Source will take advantage of many new developments (Nawin Juntong)

- Green-field 3 GeV facility with new full energy linac driven by PC gun and ring RF systems.
- Linac uses all modern features (LLRF, solid-state modulators, SLEDs)
- Storage ring cavities (500 MHz) are based on TM020 mode cavities (Spring-8)
- Solid-state RF (900 kW total installation)

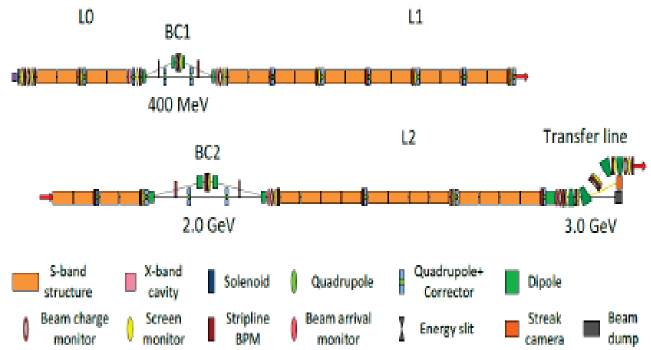
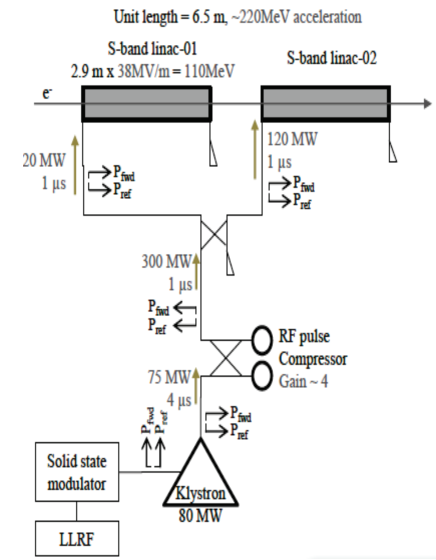
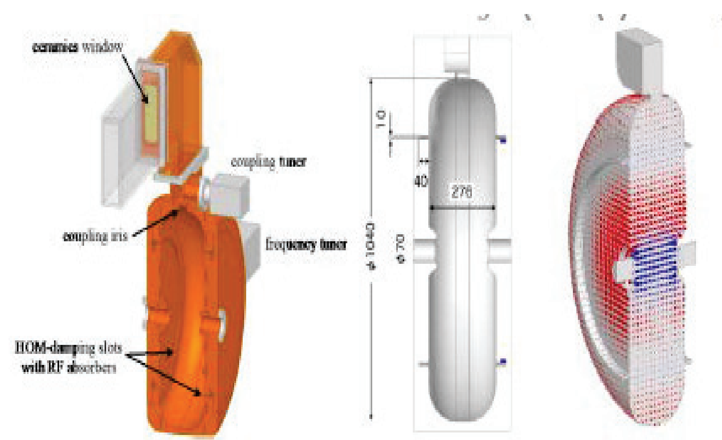


Figure 10: Schematic view of the full-energy linac injector of SPS-II. The linac injector connects to the storage ring with a vertical transfer line.

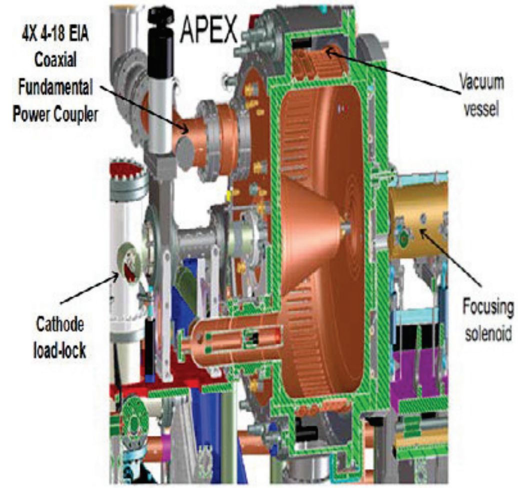


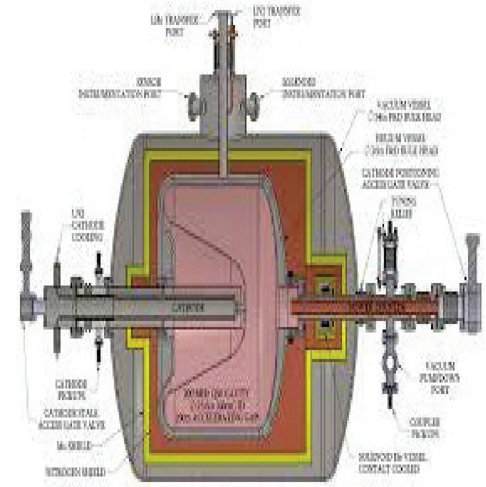


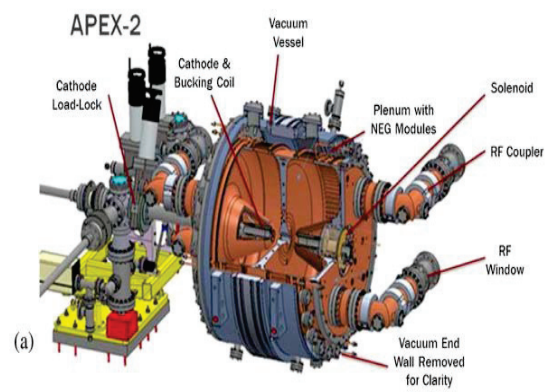
the Spring-8 TM020 cavity (H. Ego et al., PASJ2014,MOOL14)

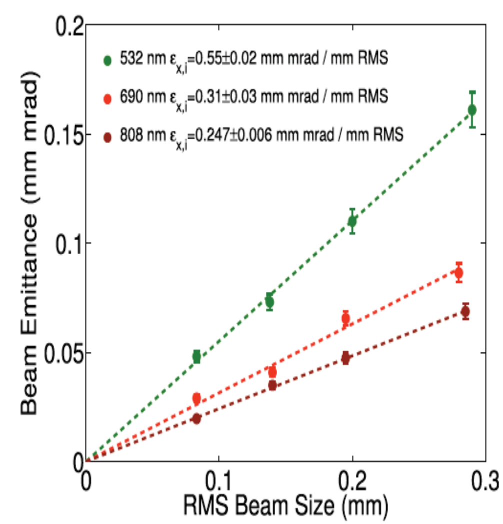
CW High Brightness PC Guns have arrived (Feng Zhou)

- High power FELs require high repetition rate (~MHz) and high brightness guns.
- CW guns can't reach the same gradient at the cathode as pulsed guns. Can they deliver high brightness? Yes!!!
- Several options have been investigated:
  - DC guns
  - SRF guns
  - NC VHF guns
- Detailed comparisons provided in the talk/paper.
- Laser and photocathode material also critical for reaching performance.
- Baseline for LCLS-II is a NC VHF gun with CsTe2 PC.
- Commissioning for LCLS-II 1 MeV source starts late April 2018 for 1+ yrs. Full injector up to 100 MeV starts 2020.
- R&D is underway for next generation CW guns with factor 2 lower emittance. Both NC and SRF guns are promising.





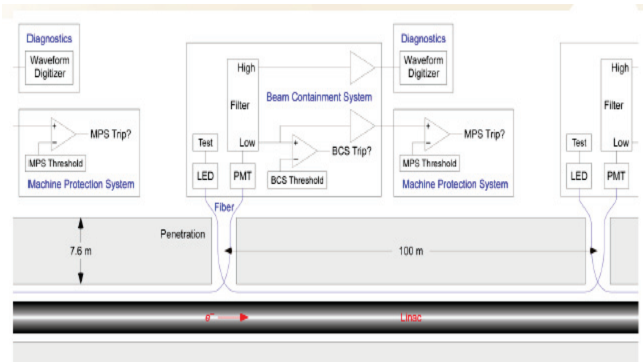


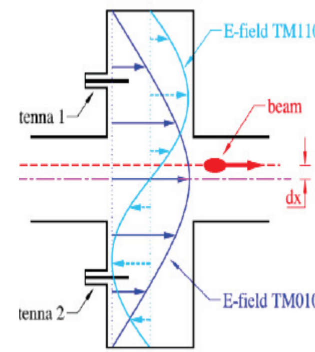


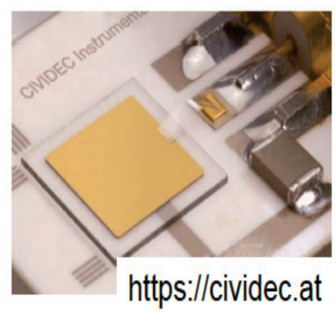
Cultrera et al, APL 108, 134105 (2016)

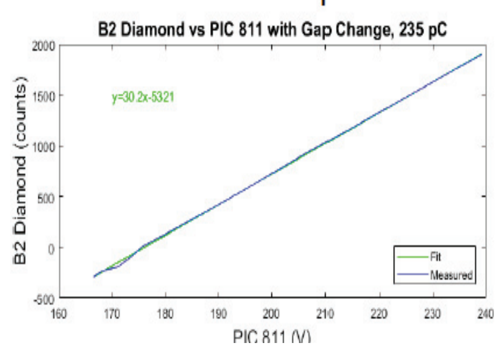
Beam Containment Systems for 250 kW-class CW electron linacs are challenging (Christine Clarke)

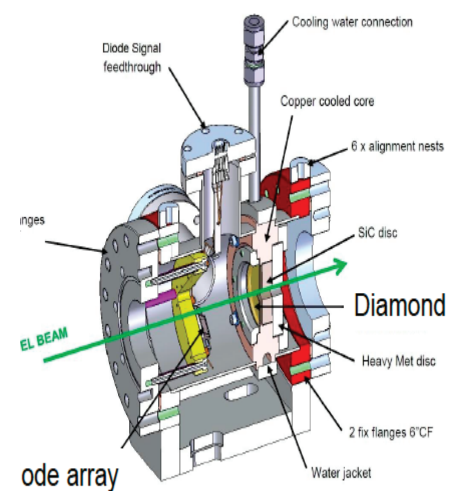
- High power electron beams for CW FELs present many challenges for personnel safety and machine protection.
- FEL transport lines also require protection against high power FEL beams.
- New-to-BCS technologies are being deployed
  - Cavities with FPGA processing
  - Cherenkov fiber beam loss monitors
  - Diamond beam loss monitors
  - Photo-diode X-ray monitors
  - PLCs





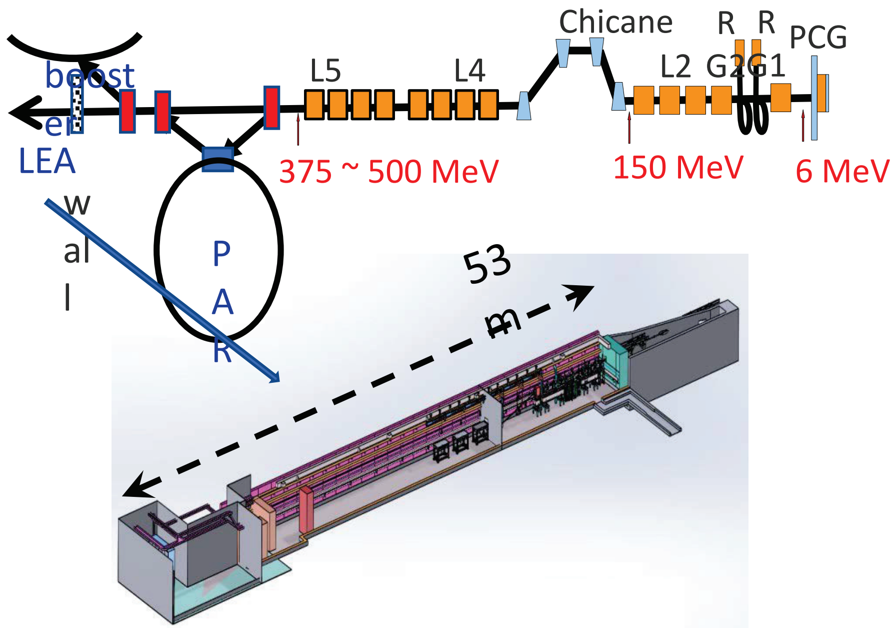


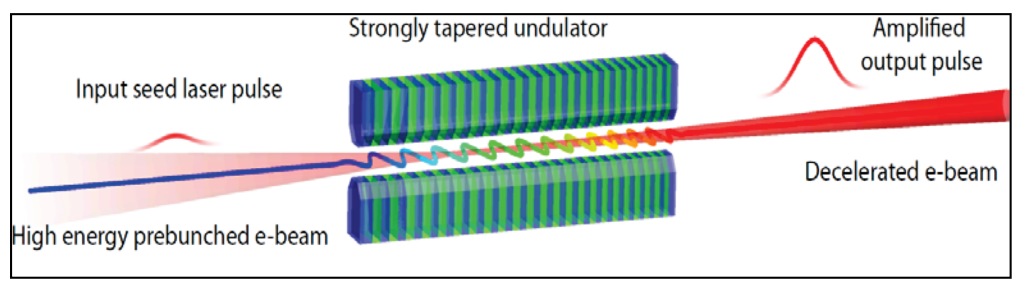




APS PC Gun is a step towards a new light source accelerator R&D capability at Argonne (Yin-e Sun)

- A new LCLS-I type PC gun has been commissioned at the APS linac.
- The gun is a step towards a proposed new light source accelerator R&D test area known as Linac Extension Area (LEA) with a 50 m tunnel and 350-500 MeV electon energy.
- Interleaving linac allows operation of LEA during APS topoff injections.
- First experiments in 2019.





Future LEA experiment: TESSA-266