SYNCHROTRON THAILAND CENTRAL LAB

RF System for the Storage Ring and Linac of the Future Synchrotron Light Facility in Thailand

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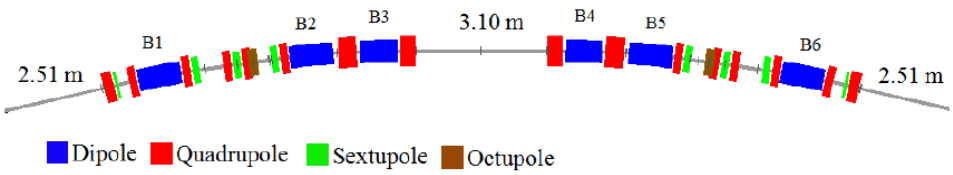
Outline

- Future light source facility in Thailand
- RF components
  - Injector
  - Storage ring
- RF systems
  - Injector
  - Storage ring
- Conclusion

Future Synchrotron Light Facility

- No OFFICAIL name yet, now it is SPS-II (Siam Photon Source –II)
- 14 cells-DTBA lattice
- 3.0 GeV 300mA maximum
- Emittance ~ 1 nmrad
- 321.3 m circumference
- 500 MHz RF system (h = 536)
- Full energy LINAC injector (S-band)

14x5m-long straight + 14x3m-short straight = 28 straight for IDs, RF, Instruments



Double Triple Bend Achromat (DTBA) Cell

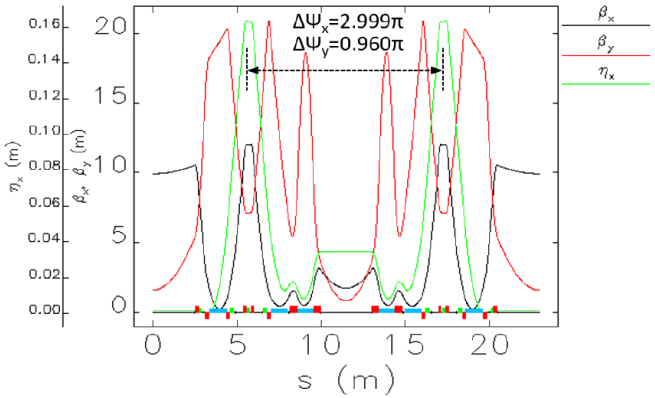


Table 1-1: Machine parameters

Parameters	SPS	SPS-II
Circumference (m)	81.3	321.3
Energy (GeV)	1.2	3.0
Relativistic gamma γ	2348.34	5870.85
Emittance ε_{x0} (nm·rad)	41.0	0.96
Nat. energy spread σ_E (%)	0.066	0.077
Nat. chromaticity ξ_x/ξ_y	-8.7/-6.4	-64.3/ -77.5
Tune Q_x/ Q_y	4.75, 2.82	34.24/ 12.31
Momentum compaction α_c	1.70e-2	3.18e-4
Damping times hor./ver./long. (ms)	10.7/9.8/4.7	9.5/11.1/6.1
Straight/circumference	0.33	0.35
Energy lost per turn from dipole U_0 (MeV)	0.066	0.577
RF frequency (MHz)	118.00	500.12
RF voltage (MV)	0.3	2.2
Harmonic number	32	536
Overvoltage V/U_0	4.5	3.8
Synchronous phase (degree)	167.29	164.77
Synchrotron tune	0.00460	0.00438
Nat. bunch length (mm)	29.03	2.854
Nat. bunch duration (ps)	96.8	9.5

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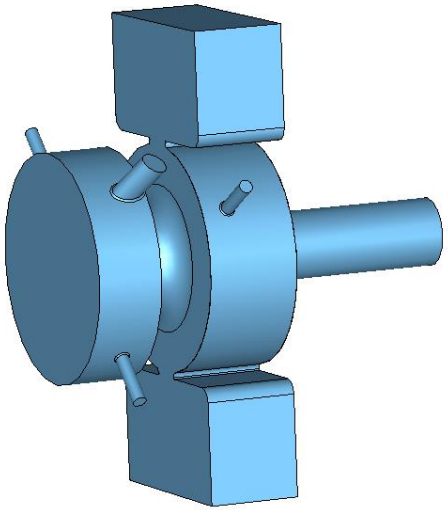
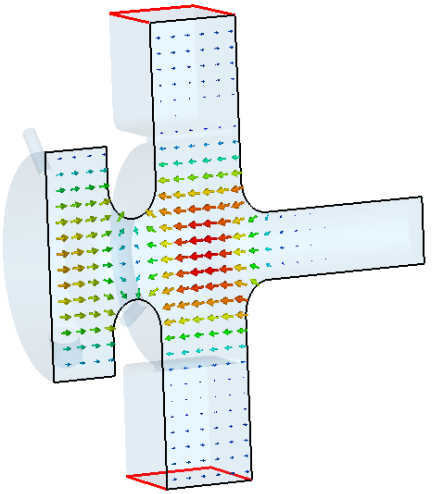
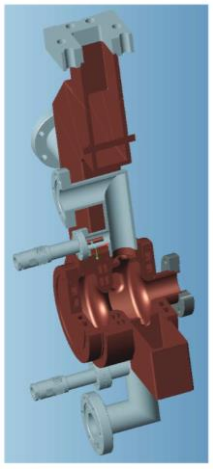
RF components -Injector

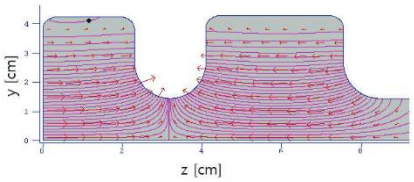
- Electron gun
  - Photocathode RF Gun, Based design is LCLS dual-feed RF gun
  - Four-ports as in PAL-XFEL will be considered



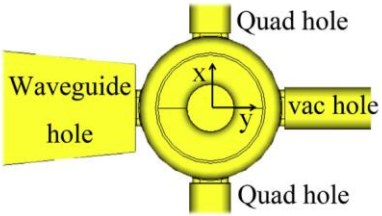
Parameters	Value
Operating frequency [MHz]	2856
Mode separation [MHz]	15
Coupling factor	2
Unloaded Quality factor	14,000
Loaded Quality factor	4,000
RF pulse width [μs]	3
Repetition rate [Hz]	60-100

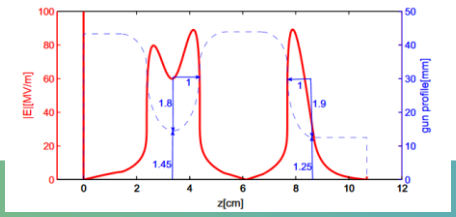






PAL-XFEL RF gun
(J. Hong et al., FEL2012, MOPD43)

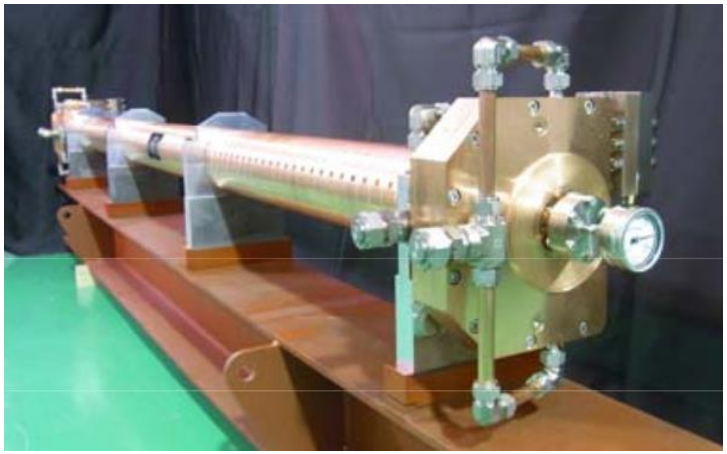




Tsinghua University RF gun
(Lianmin Zheng et al., NIM A 834 (2016) 98-107)

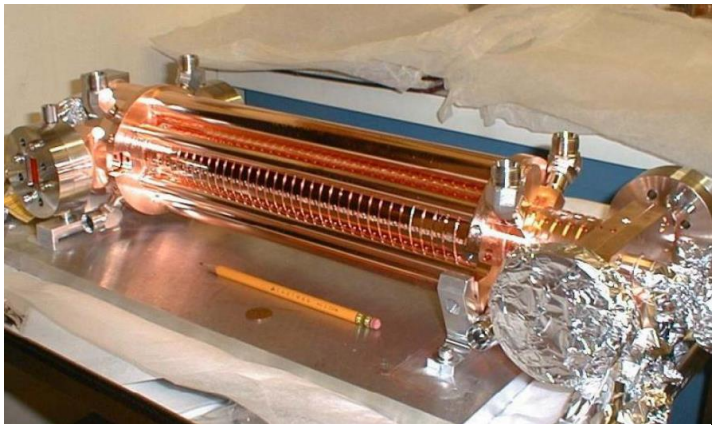
RF components -Injector

- LINAC
  - S-band structure (2856MHz)
  - High gradient > 35MV/m operation (Challenge!!!)
  - X-band structure (11.424GHz) for short pulse operation



Resonance Frequency	2,856 MHz
Phase Shift	2π/3
Accelerator Type	C.G.
Number of Cells	84+2 coupler cell
Quality Factor	13000
Group Velocity	0.012c (average)
Shunt Impedance	49.3～60.0 MΩ/m
Attenuation Constant	0.56
Filling Time	0.84 μs
Coupler type	J-type
	Quasi-summetry
Overall length	3.120 (acceleration length 2.91475) m

the 3m-long accelerating structure for PAL-XFEL
Sadao Miura et al., PASJ2012, THPS090

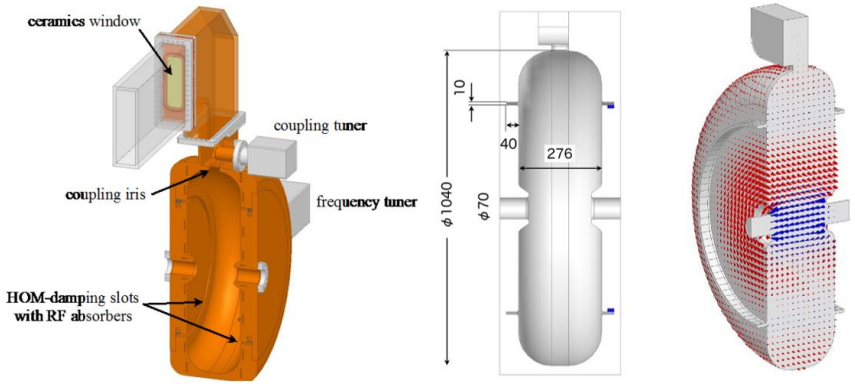


	Units	T53	H60
Structure Type		Constant Surface Field	Damped-Detuned
Total Cell Length	cm	53	60
Fill Time	ns	74	105
Phase Advance/ Cell	π	2/3	5/6
Average Iris Radius	% of λ_{rf}	13.4	17.9
Input Power for 70 MV/m Acceleration	MW	48	73

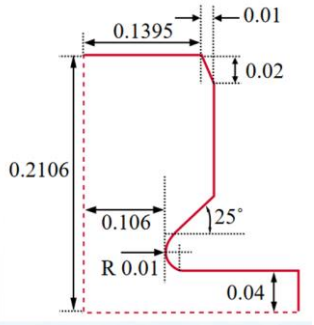
the 60 cm H60-accelerating structure
Paul Emma, LCLS-TN-01-1 and C. Adolphsen et al., LINAC2010, TUP015

RF components –Storage ring

- Main RF cavity
  - 500 MHz TM020 Spring-8 design
  - Nominal 600kV/cavity (total 6 cavities)
  - Fit in 2 of 3m-short straight (4+2 (4) cavities)



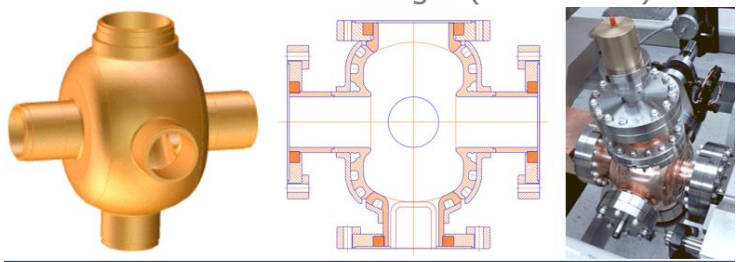
the Spring-8 TM020 cavity (H. Ego et al., PASJ2014,MOOL14)

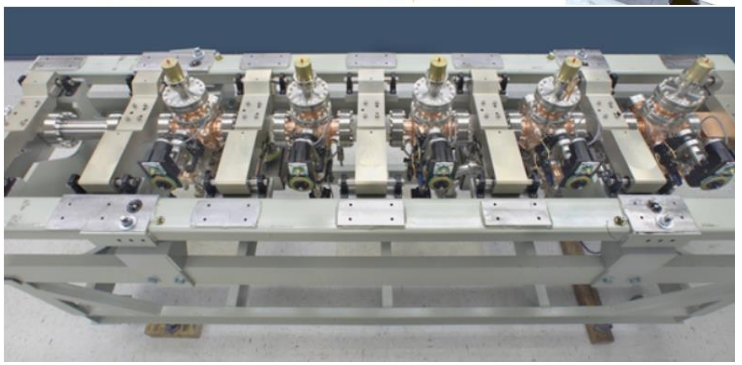


the EU-HOM damped cavity (F. Marhauser et al., EPAC2000, E. Weihreter, TUP5A01 and EPAC08, THXM03)

Property	Spring-8 TM020	EU-HOM damped
Frequency [MHz]	508.768	500
Quality factor [Q_0]	60,300	29,600
Shunt impedance [MΩ]	6.8	3.4
Maximum accelerating voltage [kV]	900	700
Insertion length [m]	0.4	0.5

- Third harmonics cavity
  - 1.5 GHz ALS, BESSY-II design
  - Passive operation (with active mode possibility)
  - Fit in 3m-short straight (5-6 cavities)





the ALS, BESSY-II third harmonic cavity
(R. Rimmer et al., EPAC98, TUP20F and M. Georgsson et al., NIM A 469 (2001) 373-381)

Table 1: Harmonic cavity system parameters

Frequency	1.5 GHz
total voltage	500 kV
bore diameter	5 cm
cavity R/Q*	80.4
calc. Q	27677
calc. Rs	2.23 MΩ
Rs x 70%	1.56 MΩ
number of cells	4
power per cell	5.01 kW

*$R=V^2/2P$

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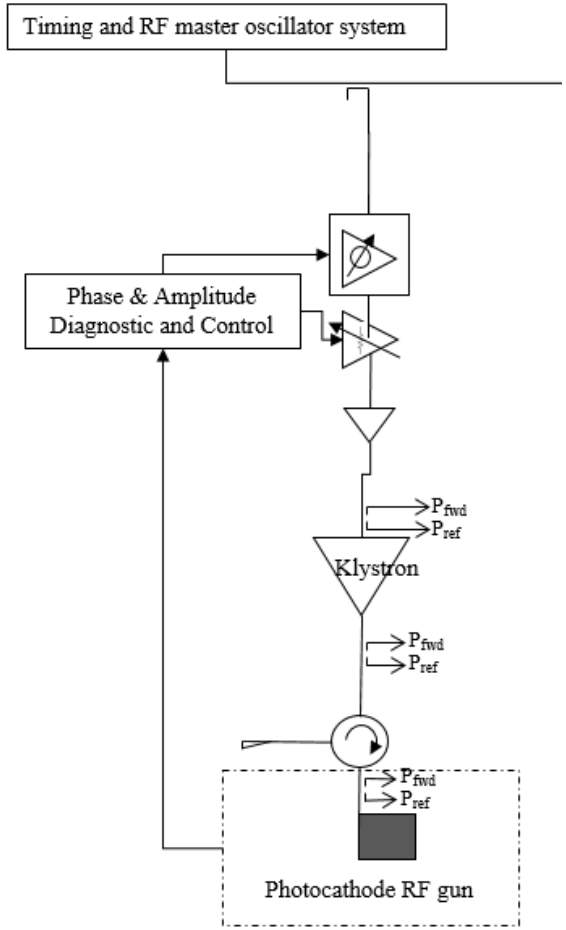
RF systems -Injector

- RF gun
  - Required at least 30MW peak power for 120MV/m accelerating gradient (LCLS)
  - 40 MW Klystron + Solid State Modulator

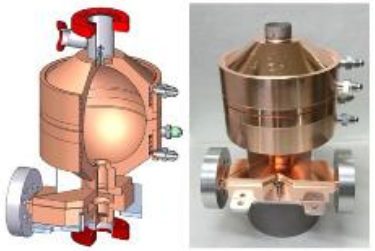
Scandinova K200 with
Toshiba E3754 Klystron



RF systems -Injector

- LINAC
  - Required 100-130MW to operate at 35-40MV/m for a 3m- structure (s-band)
  - 80 MW Klystron + Solid State Modulator+ Pulse compressor (feed 2 structures)
  - Required 75MW to operate at 75MV/m for H60 x-band structure
  - 50 MW x-band Klystron + SLED

Scandinova K400 with SLAC X-L4 Klystron 80MW



X-band SLED
Juwen W. Wang et al.,
IPAC2016, MOOCA01

Scandinova K500 with Toshiba E3712 Klystron 80MW

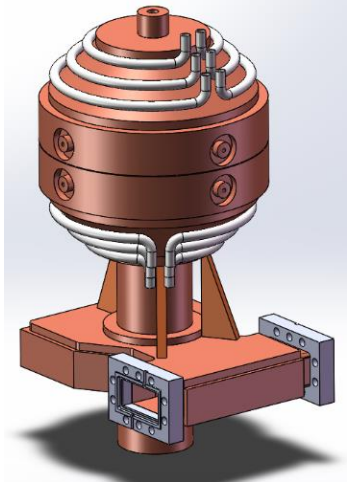


Table 1: Main Parameters of the Pulse Compressor

Pulse compressor	Parameter
Frequency	2.856 GHz
Unload quality factor	100,000
Coupling factor	8
Compression ratio	12
Input pulse length	3.6 us
Output pulse length	300 ns
Efficiency	41.6%
Peak power gain	7
Average power gain	5.2
Weight	55 kg

a new pulse compressor for S-band high-power test stand at Tsinghua University
WANG Ping et al., IPAC2017, THPIK058

RF systems -Injector

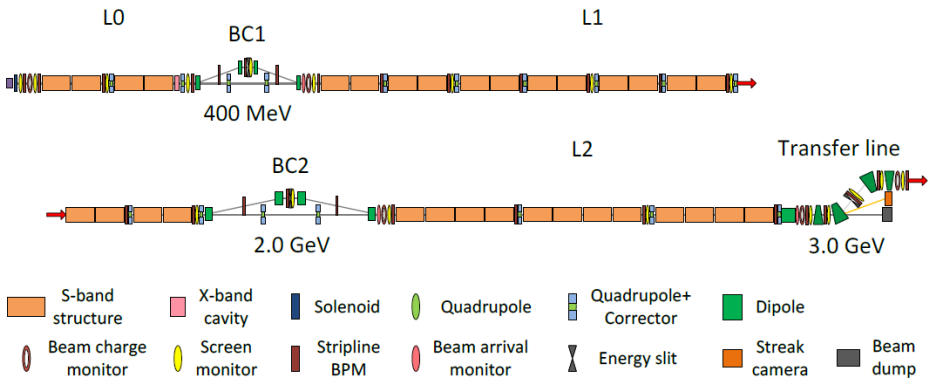
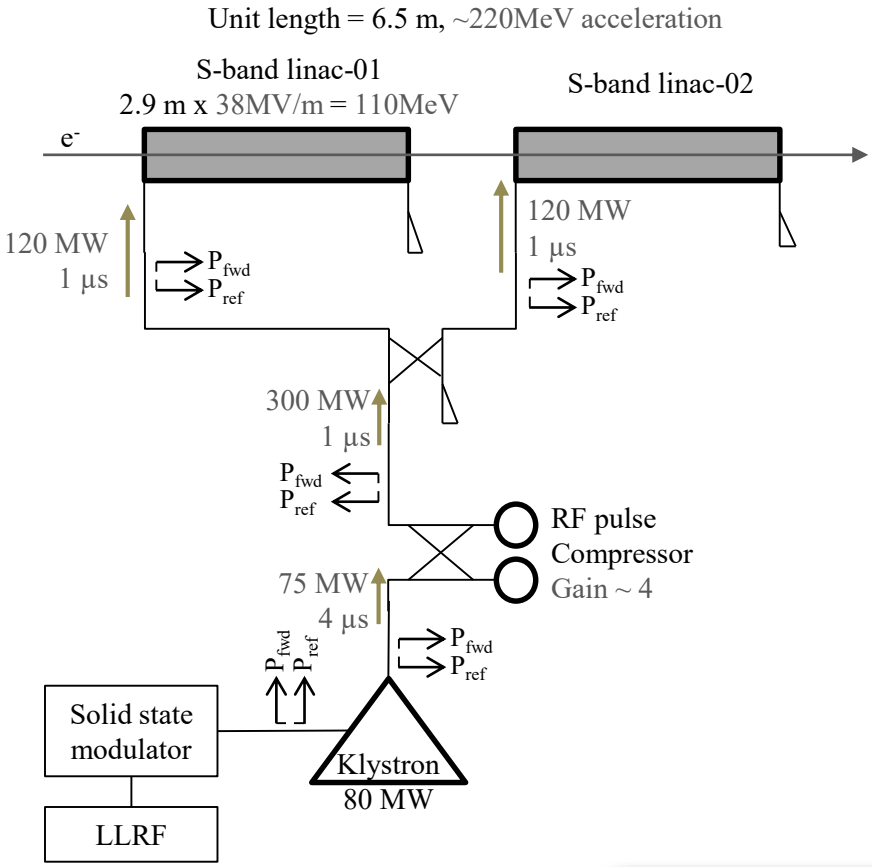


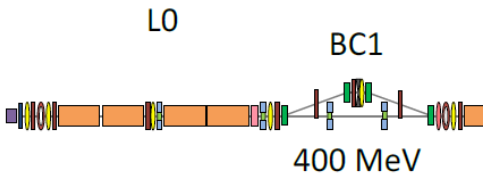
Figure 10: Schematic view of the full-energy linac injector of SPS-II. The linac injector connects to the storage ring with a vertical transfer line.

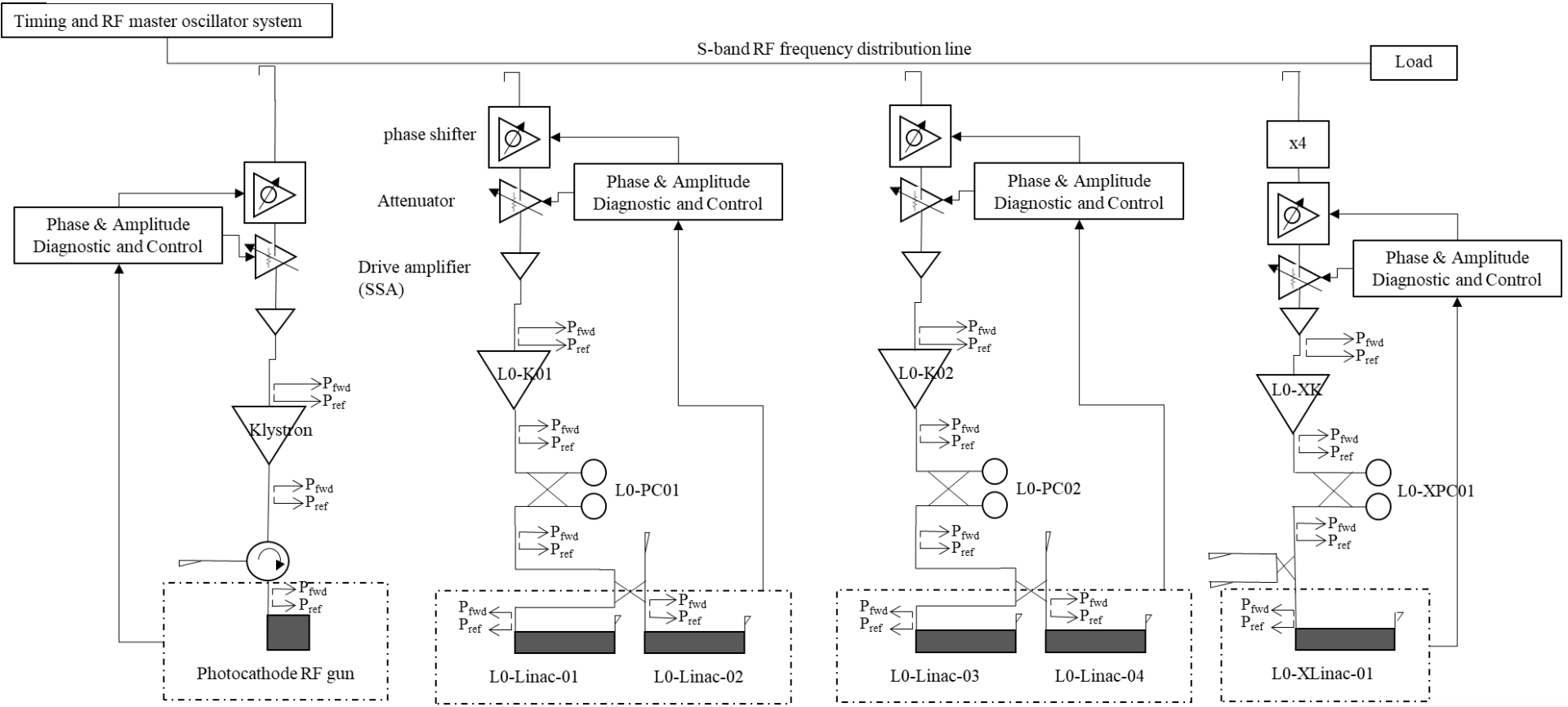
32 warm s-band linac structures + Pulse compressor (gain = 4)

- 18 units
- 2856 GHz 3.12m-linac (6.5m/unit)
- 35-40 MV/m gradient
- 3 +0.7 GeV



RF systems -Injector





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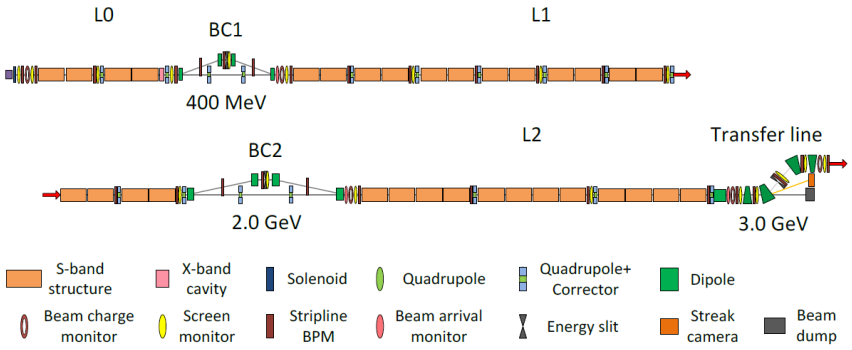
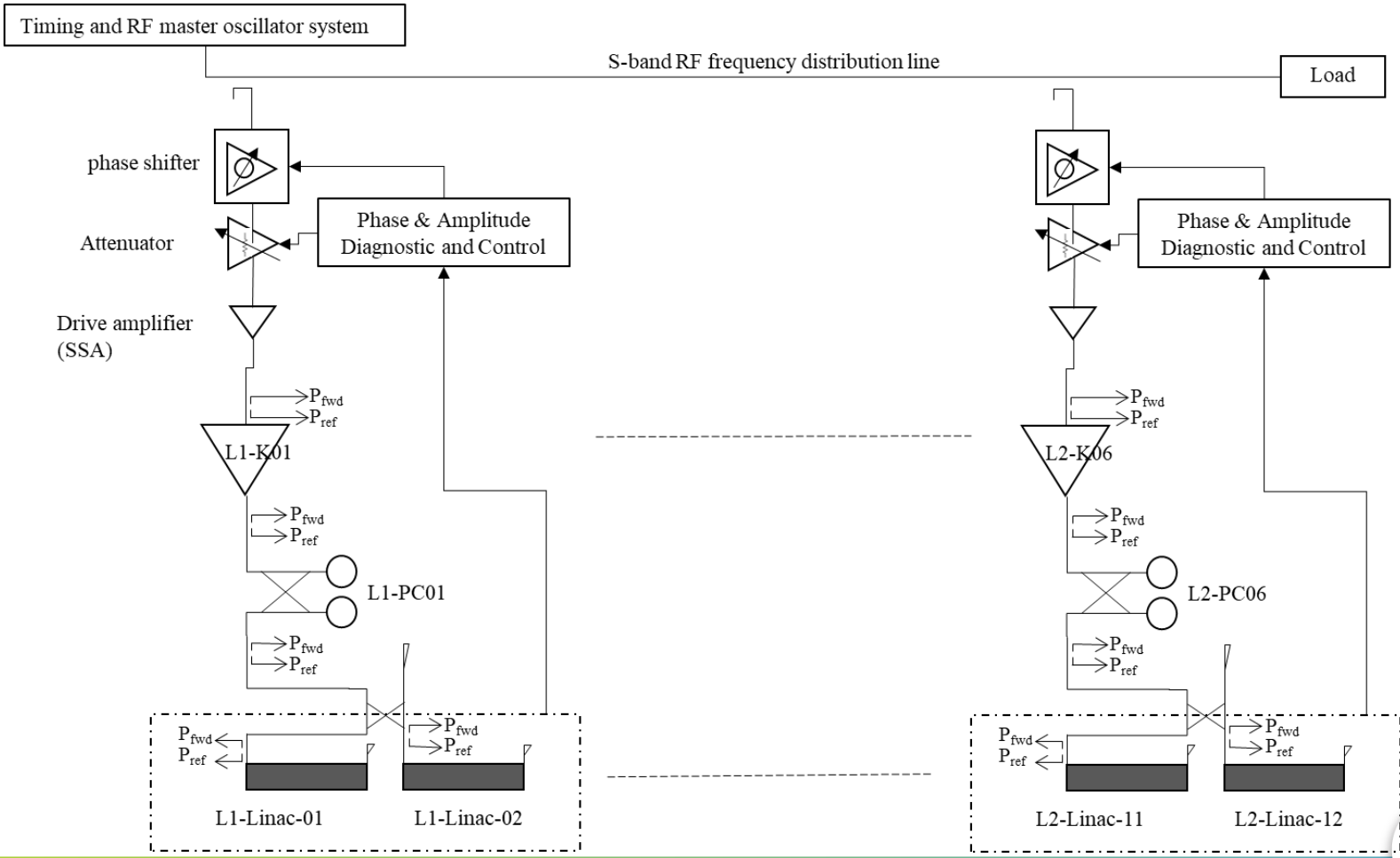
RF systems -Injector





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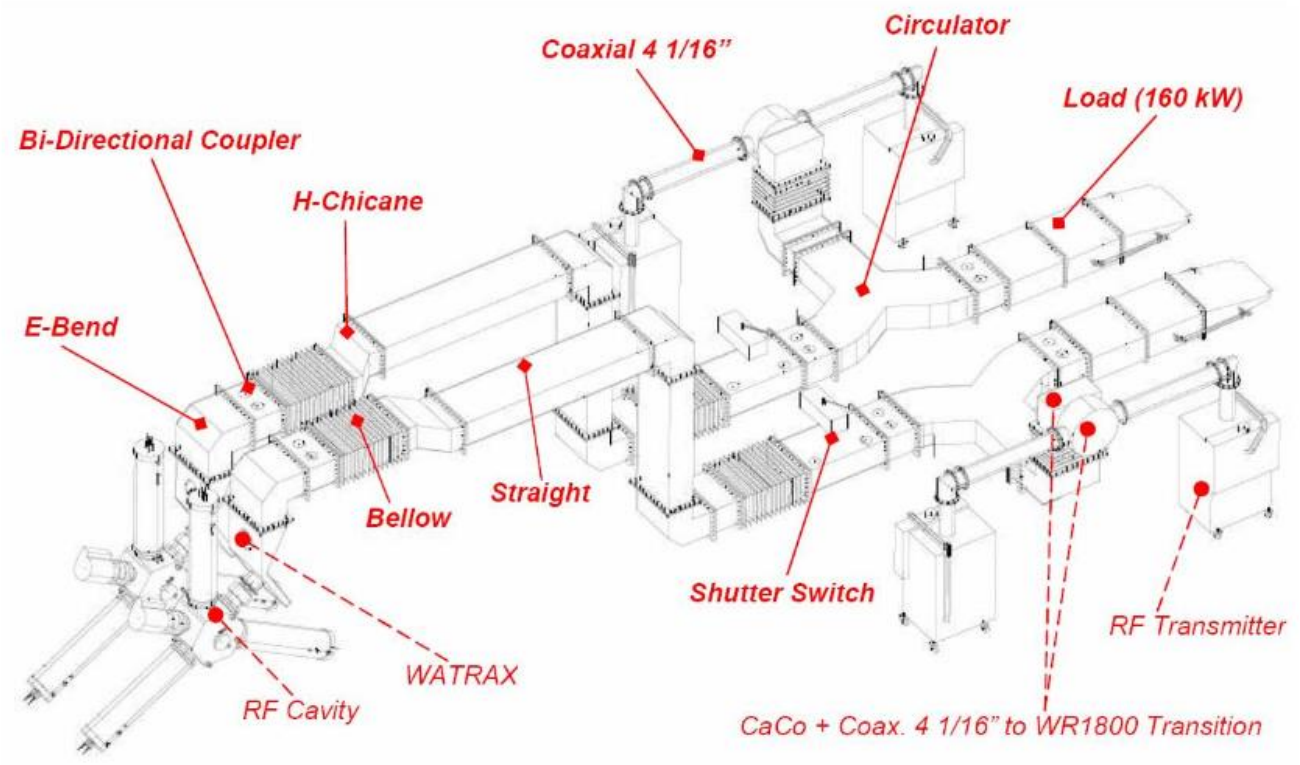
RF systems –Storage ring

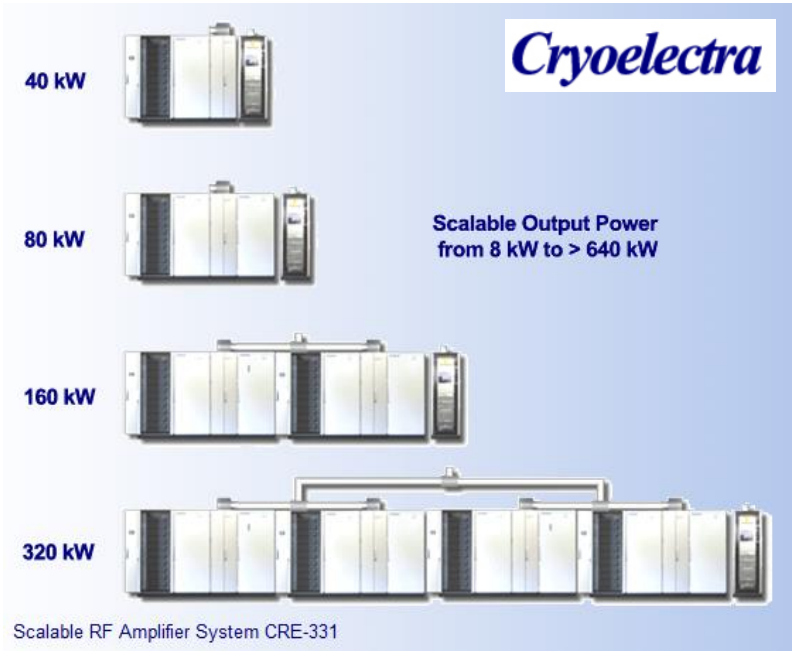
- Spring-8 TM020 cavity
  - 600 kV @ 60kW
  - Total loss with all IDs ~1.6MeV/turn (480kW@300mA)
  - Each cavity requires 150kW (80kWx2 with CaCo like in ALBA)
  - Solid State Amplifier
  - Total 6 Stations + additional 2 stations (future upgrade)



F. Perez et al., EPAC2006, TUPCH141

RF systems –Storage ring

- Cryoelectra
- Rohde & Schwarz
- AMPEGON



Scalable RF Amplifier System CRE-331

AMPEGON

Solid State based Amplifiers

The Paul Scherrer Institut (PSI) currently operates a klystron amplifier on the booster ring of the Swiss Light Source (SLS). In order to have an optional RF source for the booster cavity, PSI has developed a compact 500 MHz – 65 kW solid state RF amplifier. The amplifier design has been transferred to Ampegon under an initiative supported by Switzerland's Commission for Technology and Innovation, with the intention to industrialise and commercialise it.

Amplifiers in solid state technology offer highest reliability when maximum redundancy is given. We avoid combining on RF module level as well as central DC power supply to enhance redundancy. Each RF amplifier module is equipped with its own cooling circuit to achieve best performance. This feature allows connecting the amplifier modules directly to the combiner, which can be built in stepped lambda/4 technology or as resonant combiner. Elimination of coaxial cables at the RF output maximizes the overall efficiency and increases reliability. The frequency range is between 200 MHz and 1.3 GHz with power levels up to 150 kW. The solid state amplifier system holds all needed components including water cooling system, mains distribution and safety interlocking system. Each system can be remote controlled and equipped with customer specific interfaces such as EPICS.

Applications

ROHDE&SCHWARZ

RF amplifier system for LINACs or circular accelerators

Solid-state amplifiers from Rohde & Schwarz are the ideal driver amplifiers for klystrons or inductive output tube (IOT) amplifiers or main amplifier in an accelerator chain. Rohde & Schwarz also offers broadband amplifiers for use in feedback loops, for example to reduce the size and energy dispersion of a particle beam within a storage ring.

Rapid RF output signal suppression using fast amplifier mute option

The fast amplifier mute option available for certain amplifier models reduces the noise power of the RF output signal in just a few microseconds to a level very close to the thermal noise floor of –174 dBm (1 Hz). The RF signal will return to the nominal output power just as quickly. The mute function is controlled via a TTL input.

RF amplifier family	Frequency range	Max. CW output power
R&S®BBA150	9 kHz to 6 GHz	2.5 kW/200 W
R&S®BBL200	9 kHz to 250 MHz	10 kW
R&S®TxR9	87.5 MHz to 108 MHz	80 kW
R&S®TxV9	170 MHz to 254 MHz	32 kW
R&S®TxU9	470 MHz to 862 MHz	80 kW

Conclusion

- SPS-II (future light source in Thailand) will utilize DTBA lattice and full energy s-band linac
- Storage ring consists of 14x5m-long straight and 14x3m-short straight, which is 28 straight in total for IDs, RF, Instruments, etc.

- Four ports RF photocathode gun will be used as an e-gun
- 32 of 3m-high gradient (>35MV/m) s-band structure will be utilized for linac
- RF power for e-gun and linac will be a high power klystron with modular modulator (solid state) and pulse compressor systems

- Storage ring is based on 500 MHz RF system.
- Six of the Spring-8 TM020 RF cavity will be utilized for storage ring with the SSA systems
- Six of 160kW RF stations will be used for storage ring

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