Magnet Design for Siam Photon Source II

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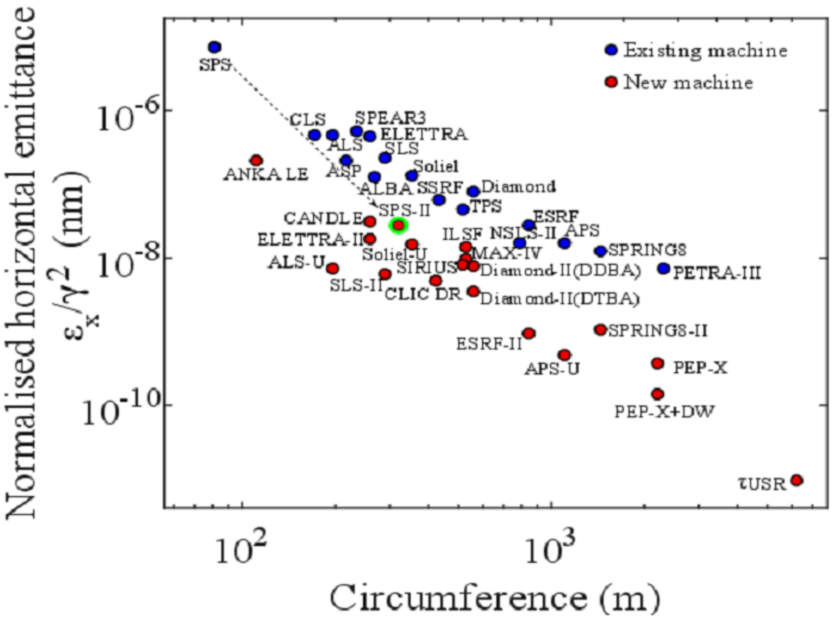
Siam Photon Source II Project



Requirements

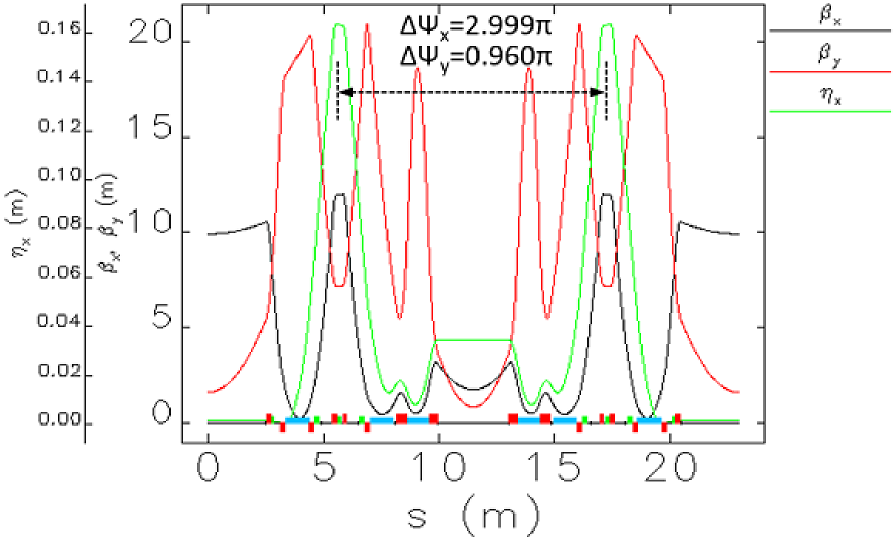
- Ring circumference **below 400 m**
- **3 GeV** electron beam energy
- Maximum beam current at **300 mA**
- Beam emittance **below 1.0 nm·rad**
- Moderate magnet requirements
- Minimum total budget
- Feasibility for existing technologies

Courtesy of T. Pulampong

Siam Photon Source II Project

Accelerator design	
Beam energy	3 GeV
Beam current	300 mA
Emittance (x)	0.96 nm·rad
Lattice structure	DTBA (14)
STR Circumference	321.3 m
RF voltage	2.2 MV
Injector	Full-energy linac

TUPGW072 (Injector design)



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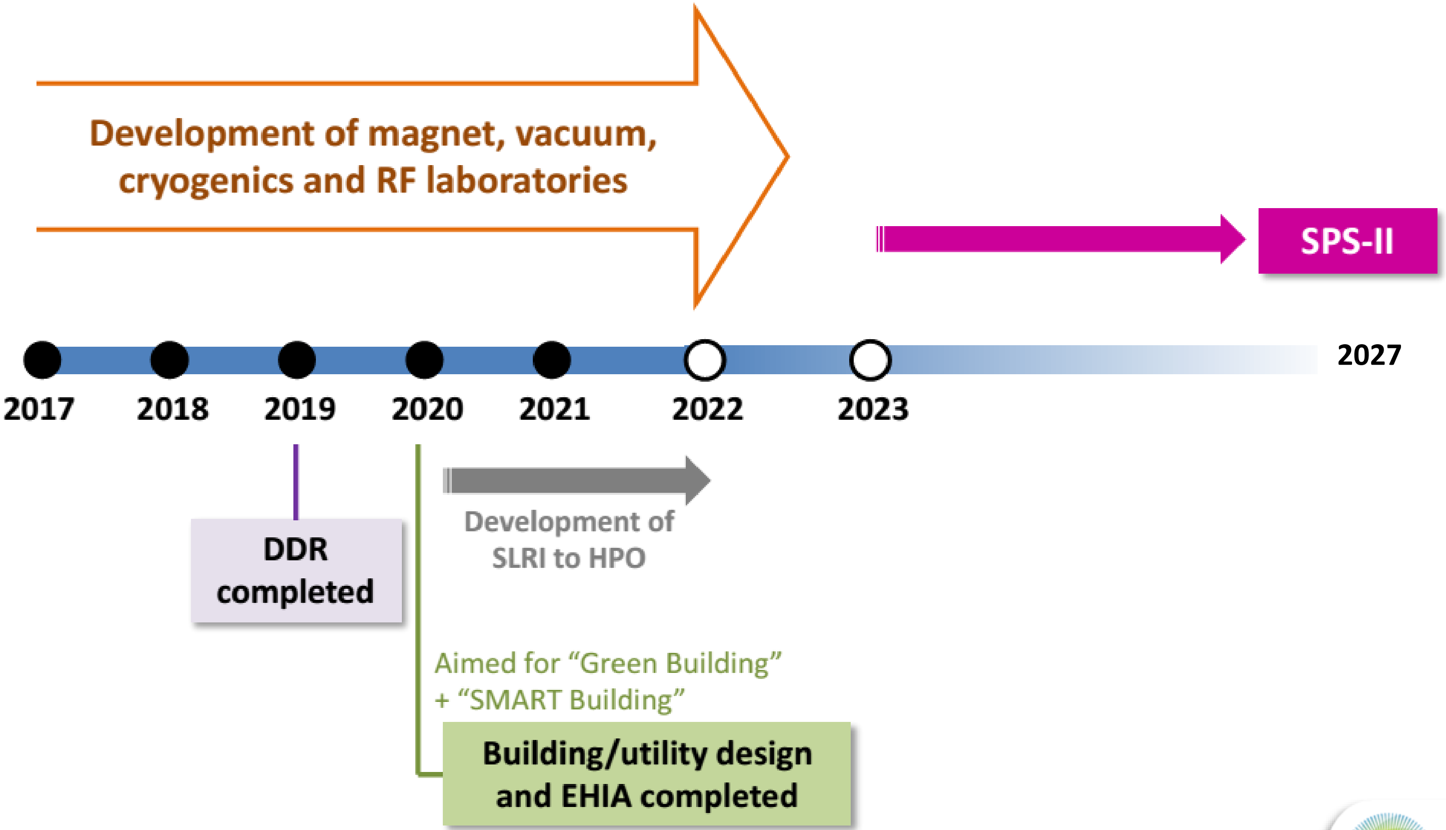

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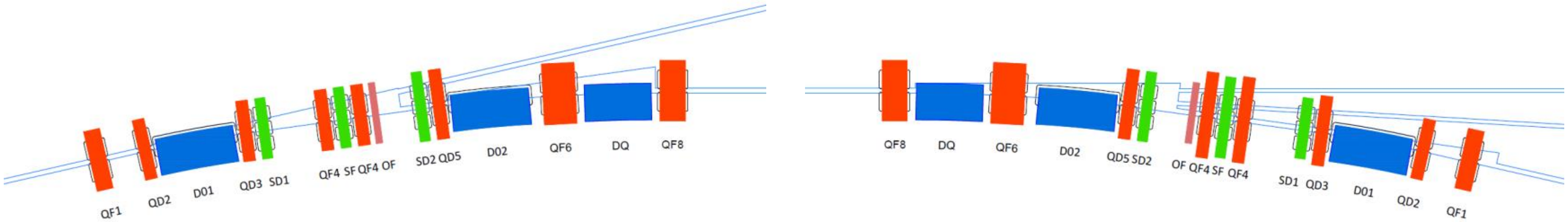
STR Magnet Requirements

Parameters	D0	DQ	QF4	QD, QF1, QF6, QF8	SD1	SD2, SF	OF1	COR
Effective length (m)	1.000	0.850	0.162	0.162 - 0.412	0.140	0.140	0.090	0.100
Dipole field (T)	0.87	0.6	-	-	0.057	0.057	-	0.08
Quadrupole field (T/m)	-	27.1	44	45 - 60	0.57	0.57	-	-
Sextupole field (T/m^2)	-	-	-	-	2030	1140 - 1450	-	-
Octupole field (T/m^3)	-	-	-	-	-	-	72000	-
GFR (mm)	±14	±8	±16	±10	±13	±15	±15	±16
Field homogeneity	1x10^{-4}	5x10^{-3}	5x10^{-4}	5x10^{-4}	1x10^{-3}	1x10^{-3}	5x10^{-3}	-



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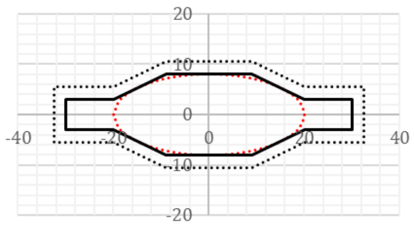
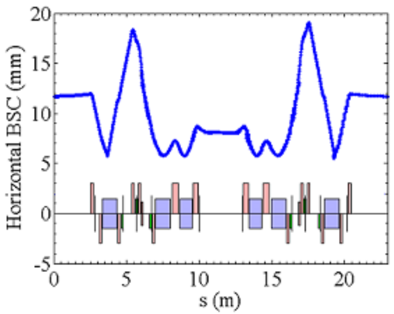
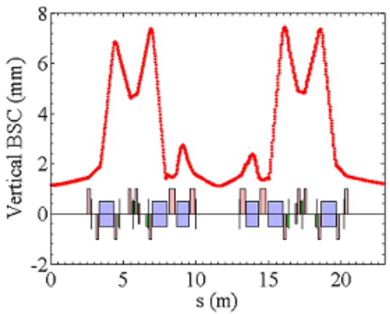
Octupole field (T/m^3)	-	-	-	-	-	-	72000	-
GFR (mm)	±14	±8	±16	±10	±13	±15	±15	±16
Field homogeneity	$1x10^{-4}$	$5x10^{-3}$	$5x10^{-4}$	$5x10^{-4}$	$1x10^{-3}$	$1x10^{-3}$	$5x10^{-3}$	-



Sketch of vacuum chamber cross-section for magnet design





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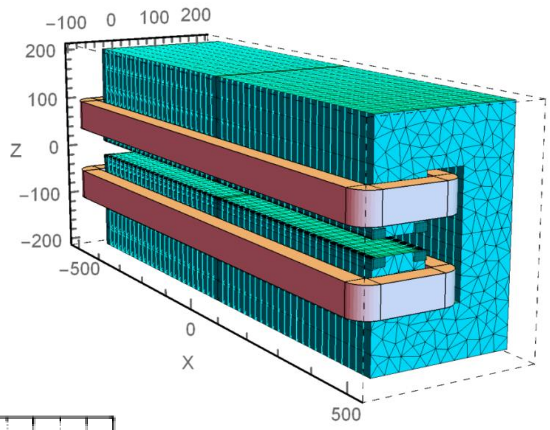
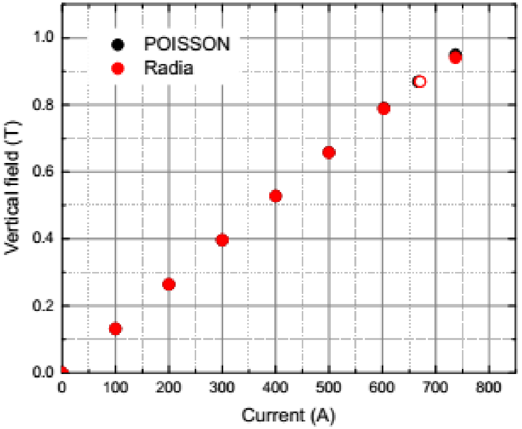
Dipole Magnet 0.87 T

Parameter	Value
Dipole field	0.87 T
Magnet gap	30 mm (full)
Effective length	1000 mm
Physical length	962 mm
Turn number	16
Conductor size	7 mm x 12 mm, ∅ 3 mm
Operating current	670.7 A
Cooling circuit	2 per coil
Temperature rise	< 6.0 °C at 2 bar (5 L/min)
Power	7.9 kW
Field homogeneity	Better than 1×10^{-4}
$\Delta B_n/B_1$	$< 1\times10^{-4}$
GFR	±14 mm
Optimization margins	±5%

Shims on the pole surface and also on both ends of the magnet for improving the field quality





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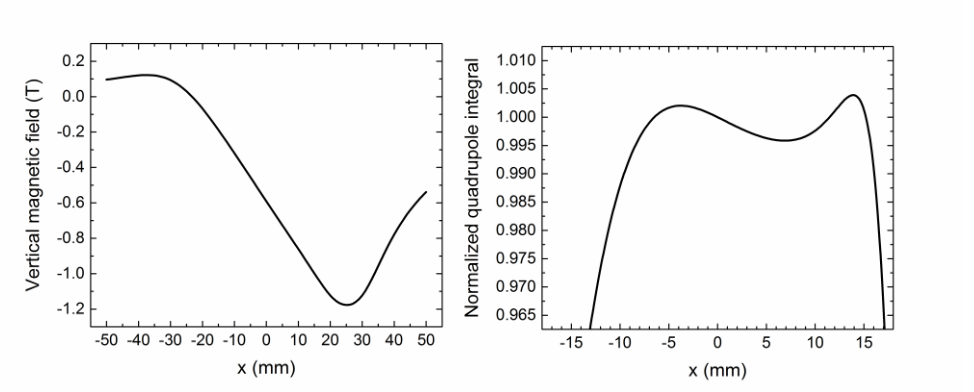
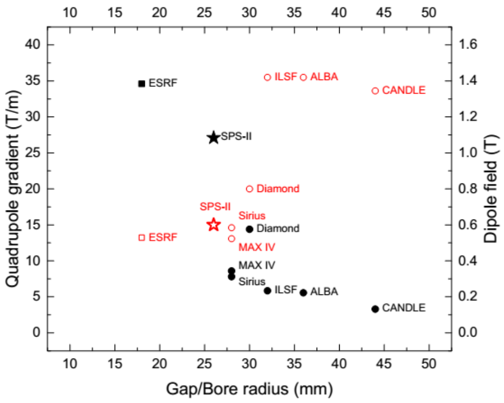
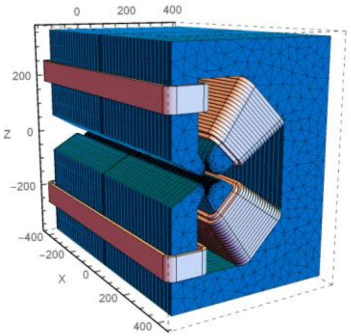
Dipole-Quadrupole Magnet 0.6 T, 27.1 T/m

Parameter	Value
Dipole, quadrupole fields	0.6 T, 27.1 T/m
Pole radius, offset	26 mm, 22.2 mm
Effective length	850 mm
Physical length	820 mm
Turn number	35 (7)
Conductor size	8.0 mm x 8.0 mm, ∅ 4 mm
Operating current	210 A
Cooling circuit	2 (1) per coil
Temperature rise	< 7°C at 4 bar (1 – 2 L/min)
Power	3.4 kW
Field homogeneity	Better than 5×10^{-3}
$\Delta B_n/B_1$	$< 3\times10^{-3}$
GFR	±8 mm
Optimization margins	±5%





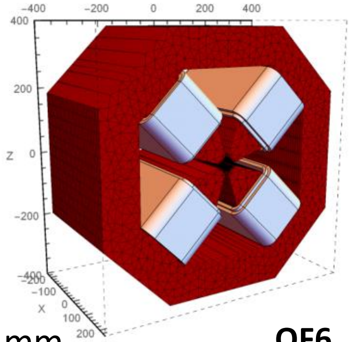


Based on ESRF's design

Quadrupole Magnets

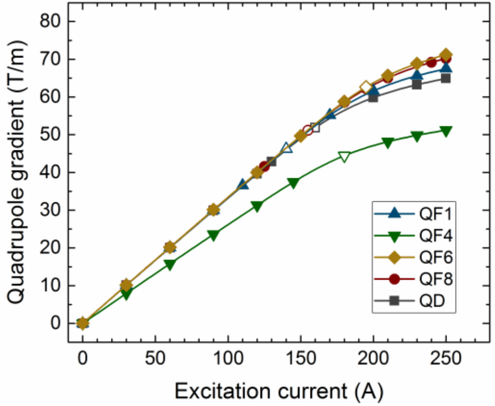
Parameter	Small R	Large R
Quadrupole field	45 – 60 T/m	44 T/m
Pole radius	16 mm	18 mm
Effective length	162 – 412 mm	162 mm
Physical length	144 – 397 mm	142 mm
Turn number	35	
Conductor size	7.0 mm x 7.0 mm, ∅ 4 mm	
Operating current	140 – 190 A	180 A
Cooling circuit	1 per coil	
Temperature rise	< 7°C at 2 – 3 L/min	
Power	1.1 – 3.1 kW	1.6 kW
Field homogeneity	Better than 5×10^{-4}	
$\Delta B_n/B_1$	$< 7\times10^{-5}$	$< 2\times10^{-4}$
GFR	±10 mm	±16 mm
Optimization margins	±20%	

Shims on the pole surface and **chamfers** on both ends of the magnet for improving the field quality



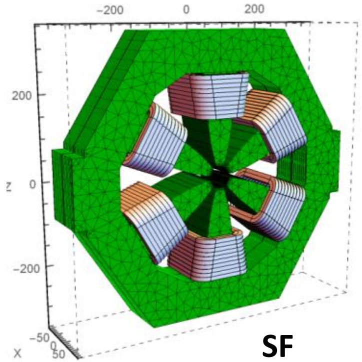
Chamfer size 3.5 – 4.0 mm

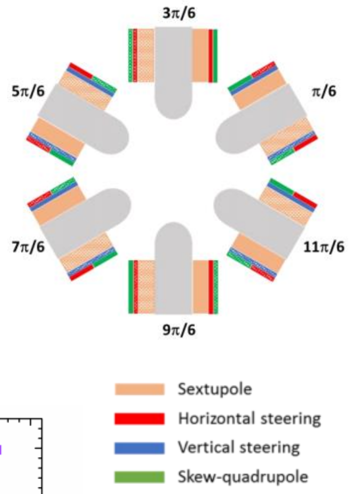
QF6

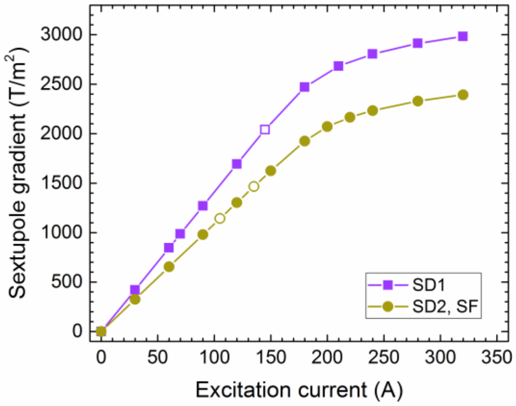


Sextupole Magnets

Parameter	Small R	Large R
Sextupole field	2030 T/m^2	1140 – 1450 T/m^2
Pole radius	22 mm	24 mm
Effective length	140 mm	
Physical length	125 mm	
Turn number	20	
Conductor size	6 mm x 6 mm, ∅ 3 mm	
Operating current	145 A	105 – 135 A
Cooling circuit	6 per magnet	
Temperature rise	< 2°C at 2 bar (2.2 L/min)	
Power	0.9 kW	0.5 – 0.8 kW
Field homogeneity	Better than 1×10^{-3}	
$\Delta B_n/B_1$	$< 5\times10^{-5}$	$< 1\times10^{-5}$
GFR	±13 mm	±15 mm
Optimization margins	±50%	







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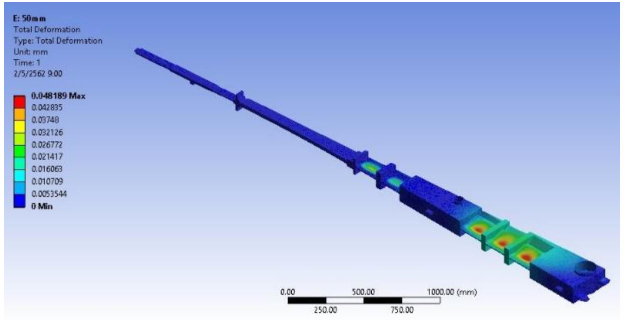
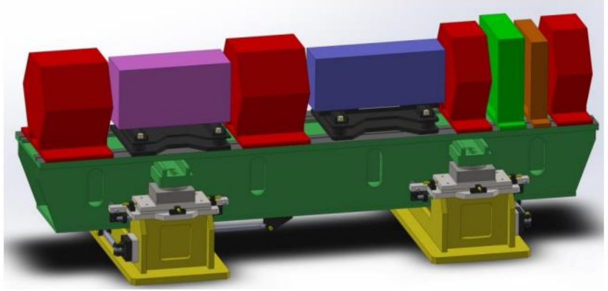
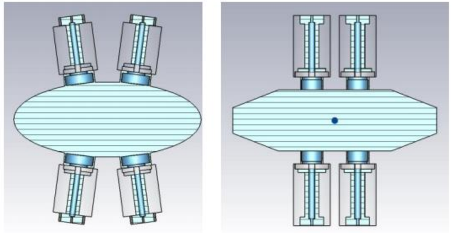
Prototype Development

- **In-house** design, fabrication and magnetic field measurement at SLRI in **early stage**
- **Collaboration** with **local manufacturing industries** in Thailand and **knowledge transfer**
- **High-precision machining** manufacturers for magnet yoke fabrication and assembly
- Transformer industries for magnet coil fabrication
- **Magnetic field measurement systems** to be developed by SLRI, simple measurement can be transferred to manufacturers during the mass production
- Prototype of other components within a half-cell: **vacuum chamber, magnet support, girders, beam position monitors**, etc.



TUPGW109 (Vacuum chamber design)





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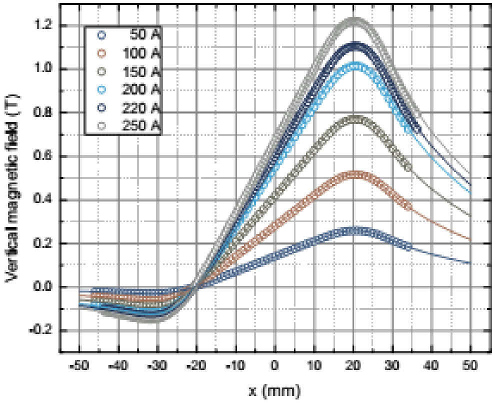
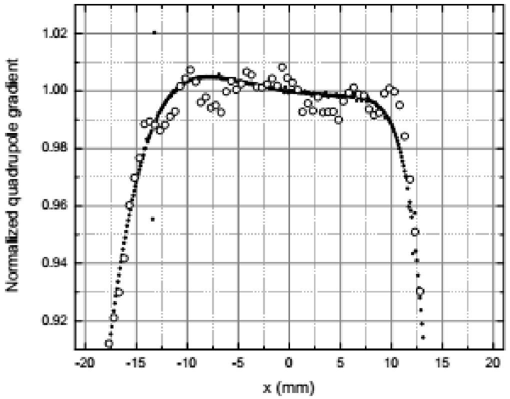
DQ Prototype

- Yoke and coils manufactured in-house
- Magnet length is limited to 300 mm due to capability of EDM wire cutting machine
- Machining and assembly tolerance between 10 – 80 μm with shims
- Improvement of engineering design for the full-scale DQ prototype
- Measured magnetic field agrees with the calculation within 1%





Sunwong, 2018

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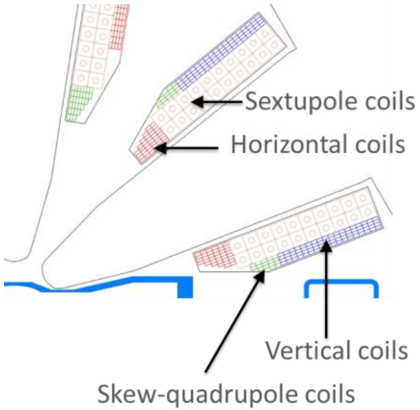
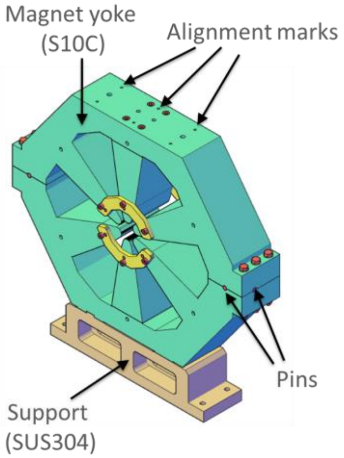
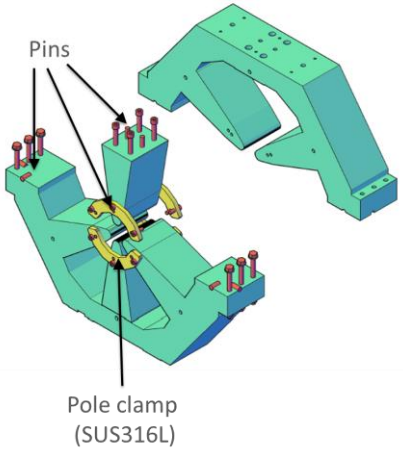
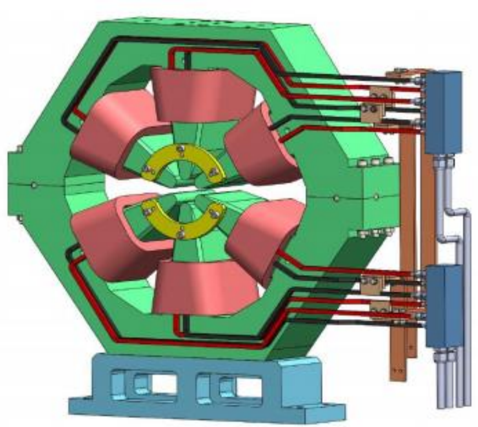
SD1 Prototype

- Yoke manufactured by local industry
- Coils manufactured by SLRI
- First SD1 made of solid steel, aim for **tolerance of 10 – 20 μm**
- Chamfer study
- Real SD1 to be made of laminated steel for fast orbit feedback system









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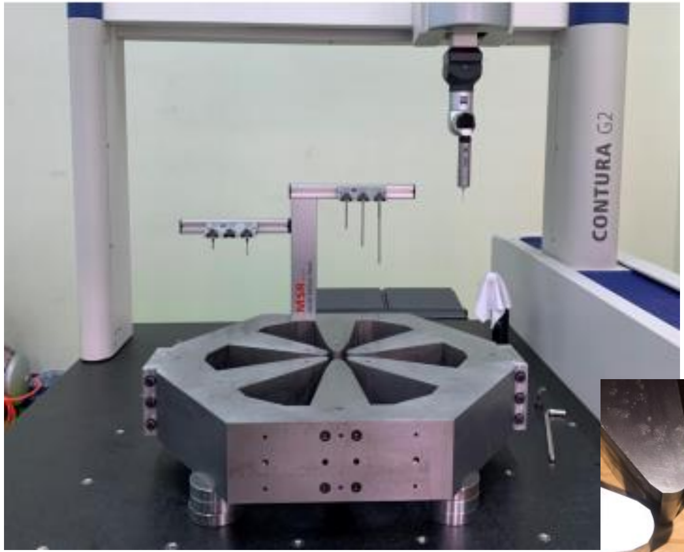
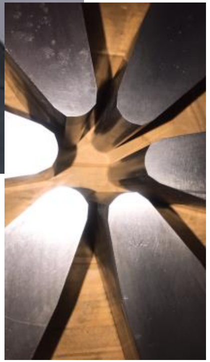
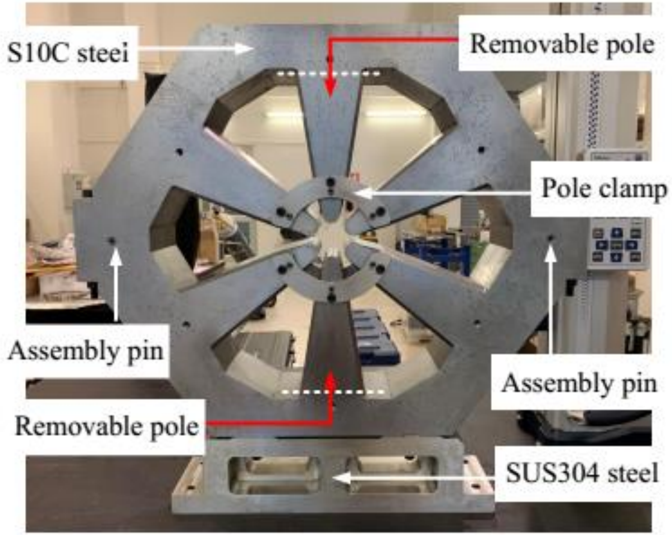
SD1 Prototype







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Concluding Remarks

Current status and ongoing works at SLRI (magnet related)

- **Prototype development for STR magnets (half-cell)**
  - Cross-check of magnetic field calculation with commercial software and investigation of magnet cross-talk
  - Optimization of coil cooling parameters for minimum cost
  - Engineering design and manufacturing drawing
  - Development of magnetic measurement system
  - Collaboration with local industries
- **Design of pulsed multipole magnet for injection**
- **Design of magnets for the full-energy linac and injector**
- **Injector installation in 2025, STR installation in 2026**
- **Estimated cost of magnet system and 5 x insertion devices → 700 Million THB / 22 Million USD**

60% domestic

2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
CDR	DDR/STR magnet design		Injector magnet design		Components production			Injector installation	STR installation	Commissioning
		Prototype development								