Paul Scherrer Institute
M. Gaspar, M. Pedrozzi, L. Stingelin, Wolfgang Tron and Ricardo Zennaro

Status and plans of the RF renewal in the framework of the Swiss Light Source upgrade (SLS2)

CWRF22, CERN, Geneva

PAUL SCHERRER INSTITUT

SLS 2.0 Synchrotron Parameters

Parameter	SLS 2.0 (TDR)	SLS
Circumference [m]	288	288
Energy [GeV]	2.7	2.411
Lattice and ID Energy loss/turn [keV]	687.6 → **943**	549→600
Energy spread	$1.16 \cdot 10^{-3}$	$9 \cdot 10^{-4}$
Momentum compaction α_c	$1.05 \cdot 10^{-4}$	$7 \cdot 10^{-4}$
Energy acceptance (without harmonic cavity)	6.2% → 5.1%	3%
Main RF frequency [MHz]	499.6537	499.6
Total main RF voltage nominal [kV]	1780	2080
Total main RF voltage maximum [kV]	2200	2600
Harmonic number	480	480
Gap in the filling pattern, empty buckets	20…**30**	50…90
Damping times x/y/E [ms]	4.14/7.54/6.41	8.4/8.4/4.5
Beta functions at main cavity location β_x [m] / β_y [m]	9.6/7.0	1.5/1.1
Beta functions at harmonic cavity β_x [m] / β_y [m]	6.8/4.1	3.5/3.5
Synchrotron frequency without harmonic cavity [kHz]	2.172	6.93
Energy fluctuations relative to energy spread	<10%	

SLS 2.0 Synchrotron Parameters

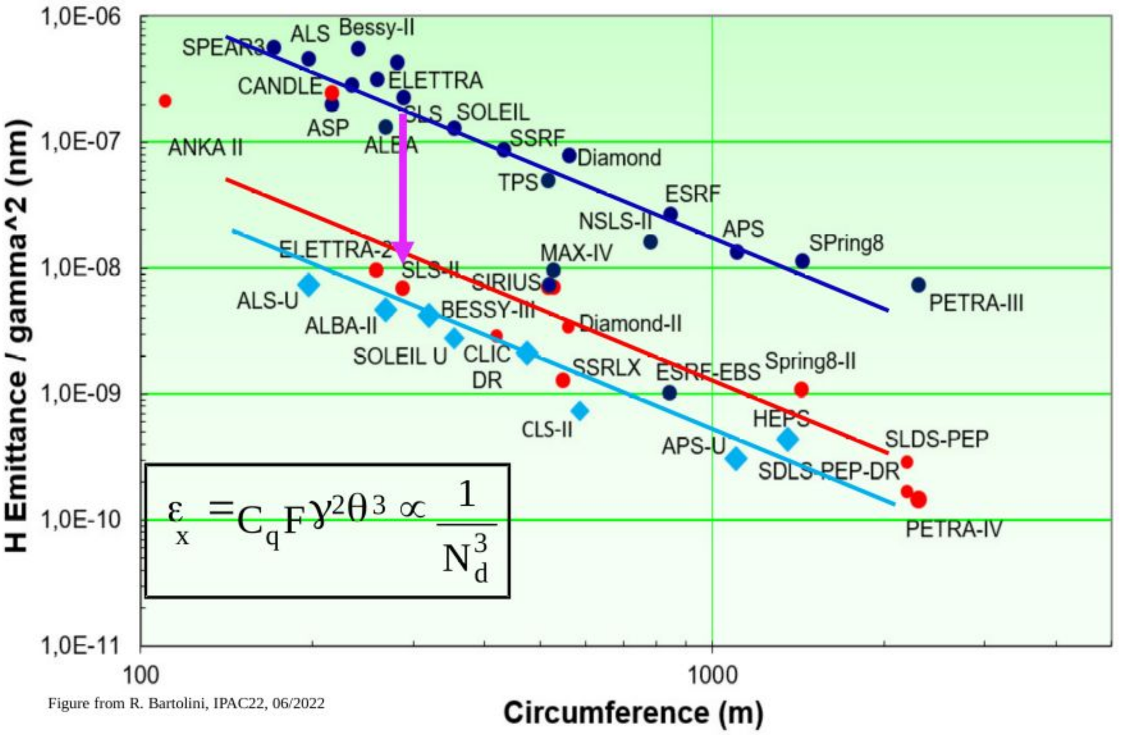
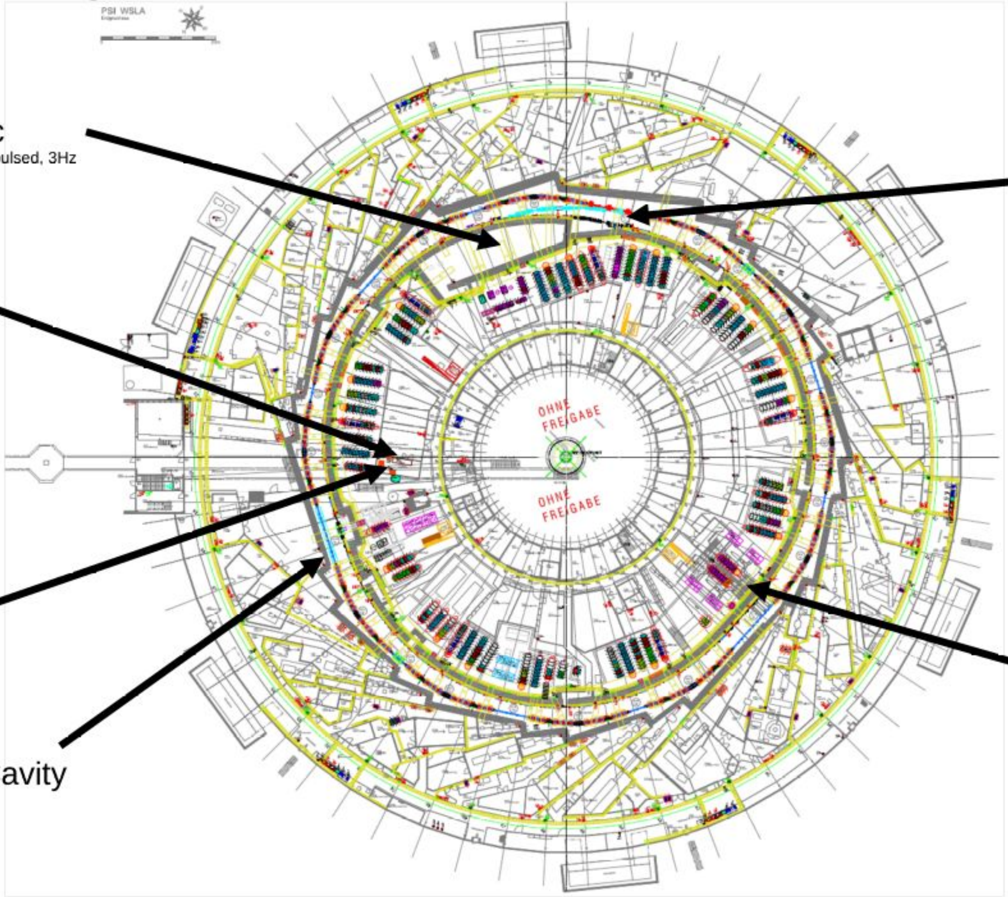


Figure from R. Bartolini, IPAC22, 06/2022

Layout SLS2 RF



SLS 2.0 RF parameters

Main RF-System	SLS 2.0		SLS
Total voltage [kV]	1440	1780	2080
Energy acceptance (without harmonic cavity)	5% → 3.7%	6.3% → 5.2%	3%
Number of cavities	4		4
Voltage per cavity [kV]	360	445	520
Wall loss per cavity [kW]	20	30	40
Required RF-power with beam and minimum ID Power [kW]	88	98.1	95
Required RF-power with beam and maximum ID Power [kW]	114	**124**	100
Optimal coupling	4.62...6.0	3.4...4.3	2.5
Detuning for matching [kHz]	-49.1...-57.1	-32.4...-44.6	-33
HOM control	By strong HOM damping		Temp. detuning
Max. voltage for ≤150kW reflected pulse power [kV] (restriction from amplifier specification)	460	540	

Amplifier Spec: 150kW

Cavity Spec. for max coupling: 8.0

Linac and Gun

Linac
Possible redesign:
- Smaller and simpler structure
- Improved performance

Gun
Possible update:
- Shorter bunch length

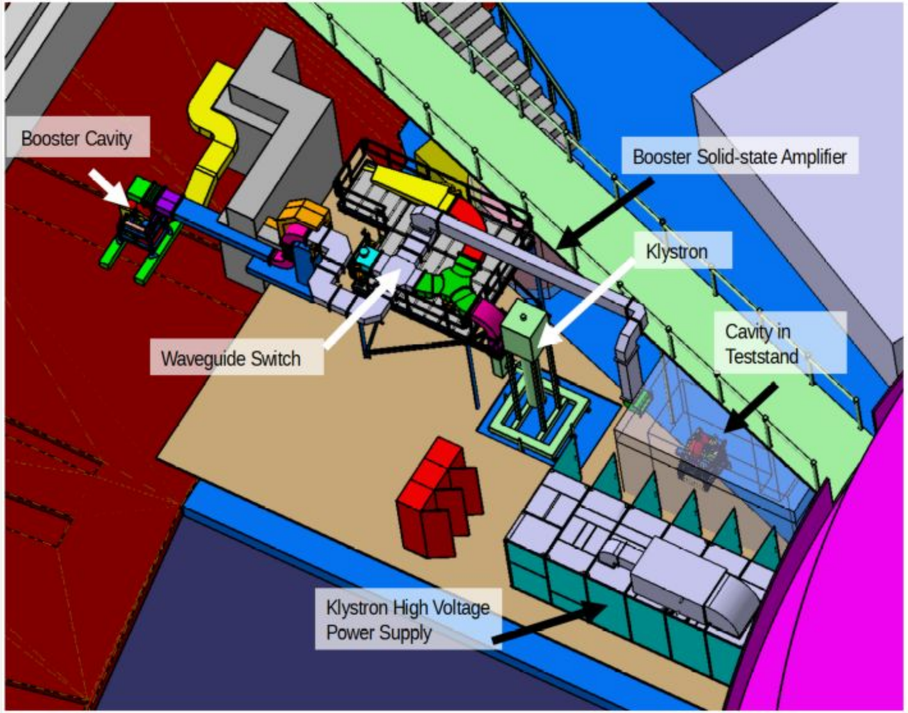
Booster - Solid-State Amplifier

Control Rack
No foreseen update

Output Transmission Line
Possible update: Conversion from coax to waveguide

Solid-state Amplifier
No foreseen update

Teststand



Teststand present update:
- Increase available area for evaluation of high power RF components.

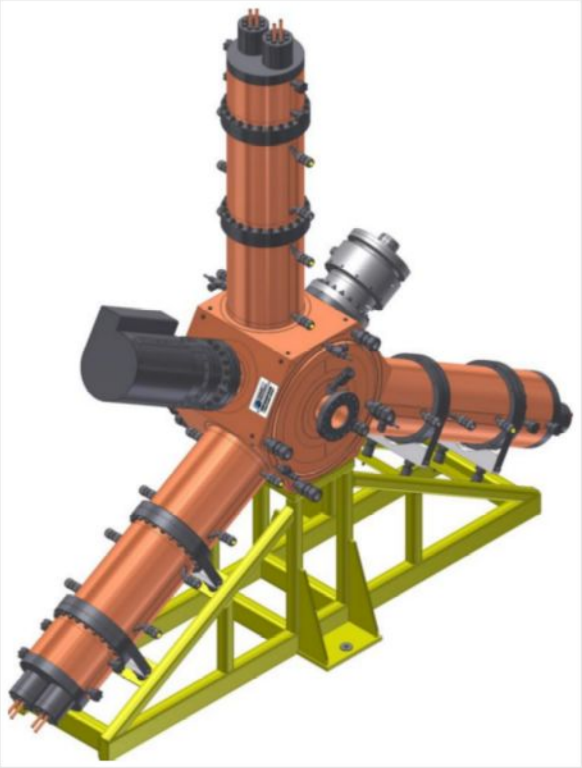
Waveguide switch:
- Operation parallel to SLS possible.

Two configurations available:
- Configuration 1 (default)
  Booster → Solid-state Amplifier, Teststand → Klystron Amplifier
- Configuration 2 (back.up)
  Booster → Klystron Amplifier, Teststand → Solid-state Amplifier

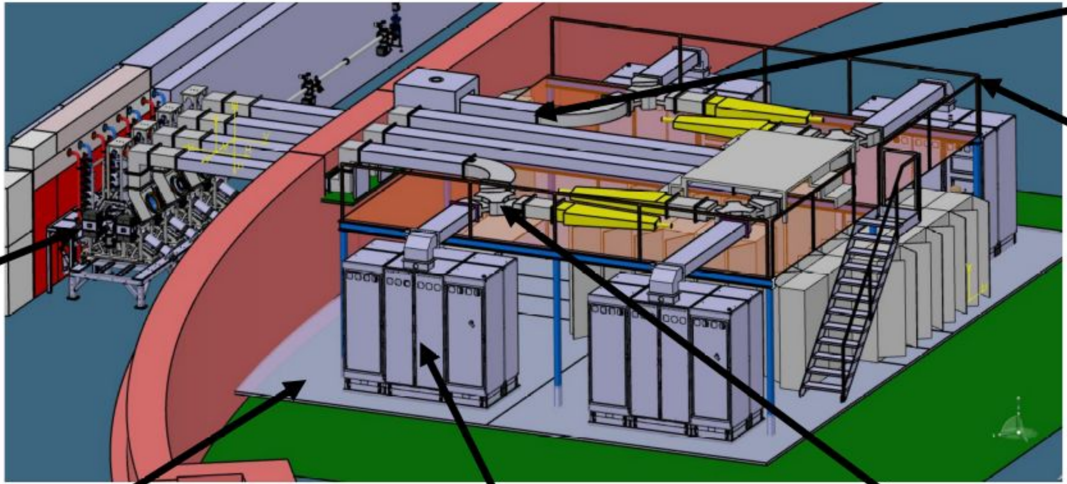
Storage Ring – Higher order mode damped cavity

*State-of-the-art HOM-damped cavity type HZB built by RI

Parameter	Value	Unit
Nominal Frequency	499.65+/-0.25	MHz
Tuning Range	+/-0.5	MHz
Shunt Impedance	3.5	MΩ
Quality factor Q_0	>28 000	
Coupling β	1...max (5)	
Eff. gap voltage at 70kW	700	kV



Storage Ring – Layout and Components



Waveguide infrastructure
- Top of the RF Systems.
- Extra room available underneath

Steel Frame
- Support for waveguide components

4x Cavities
- All in the same straight section

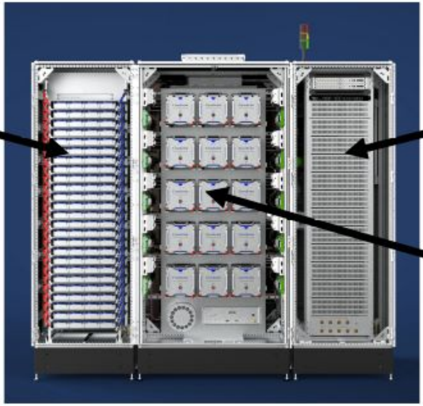
Double Floor
- Water cooling
- Mains supply
- Signaling cables
- Computer control and network

4x Solid-state RF Stations
- Waveguide RF power output at the top

High Power Circulators and Loads
- Will be kept in the beginning of operations.
- May be replaced by a by-pass later.

Storage Ring – Solid-state RF Station

Cryoelectra Solid-state RF station



Compact – Organized in 3 Racks

Tower Module
- Composed of 16 RF Units
- Easily serviceable

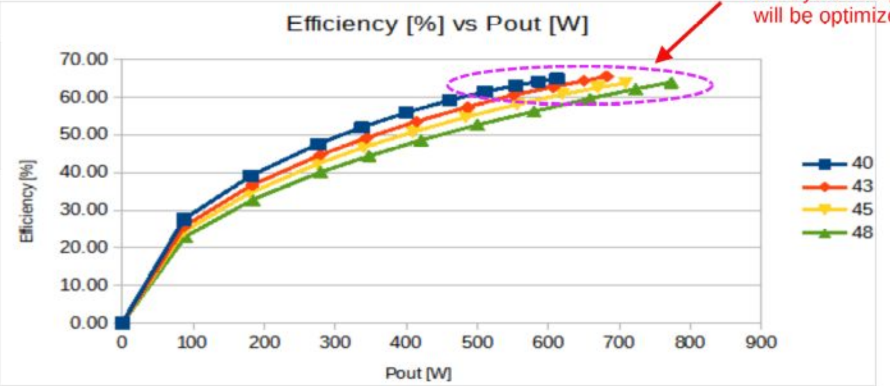
Expected RF System Performance
(PSI Specification)

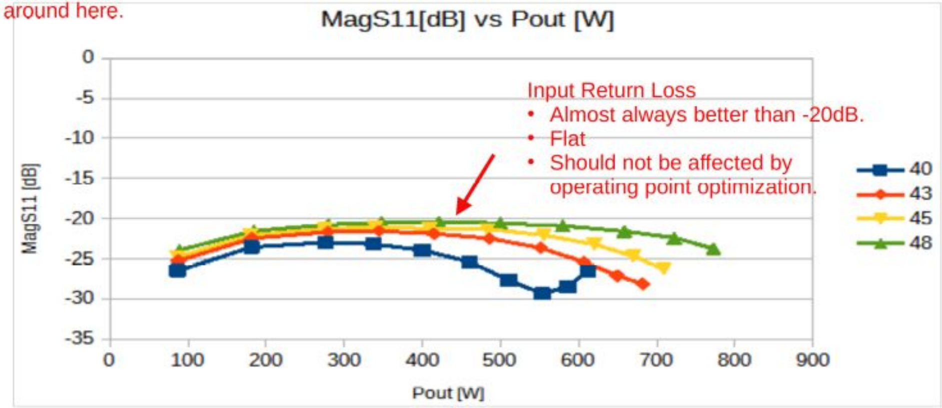
Parameter	Value
Nominal RF operating frequency	499.652MHz
Nominal RF output power	150kW
Efficiency (Wall-plug to RF)	> 56%
Power gain	>80dB
Output harmonics	< -36dBc
Spurious (including side-bands)	< -70dBc

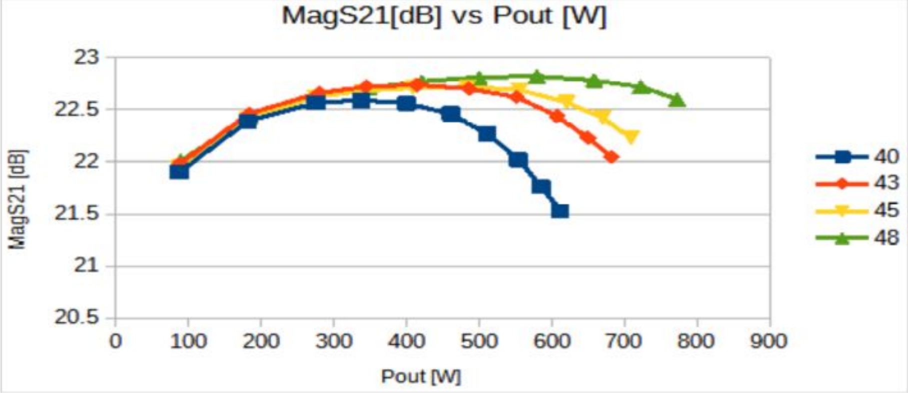
Storage Ring – Solid-state RF Station - RF Unit measurements

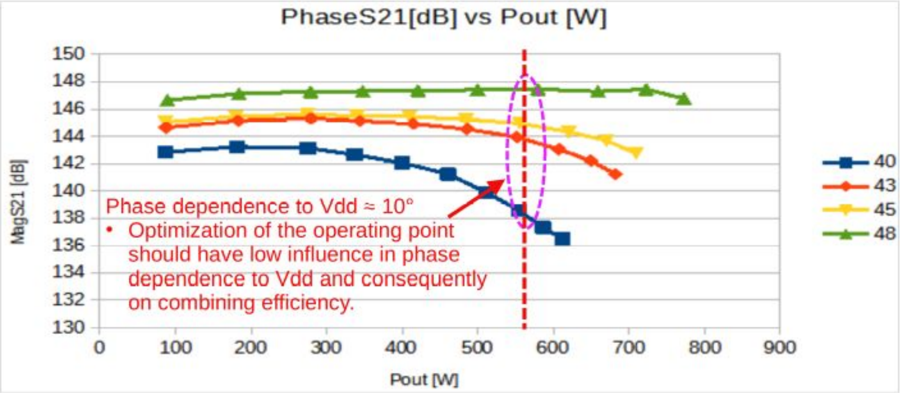
Vdd sweep - 20220831, CW Freq=500MHz

High Efficiency Region
- RF Systems operating point will be optimized around here.



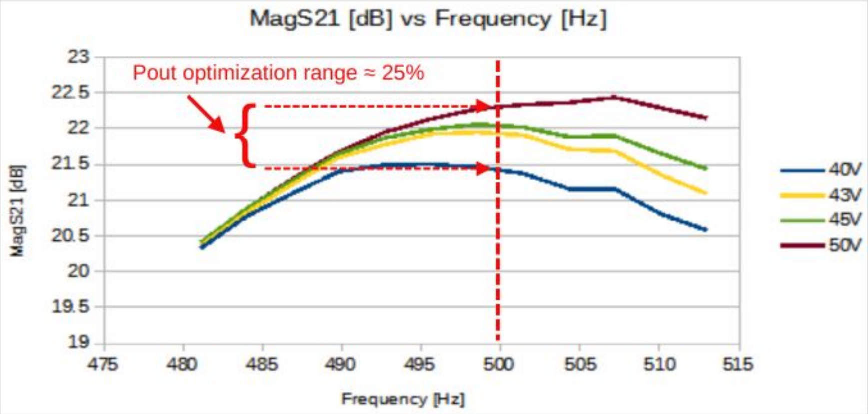


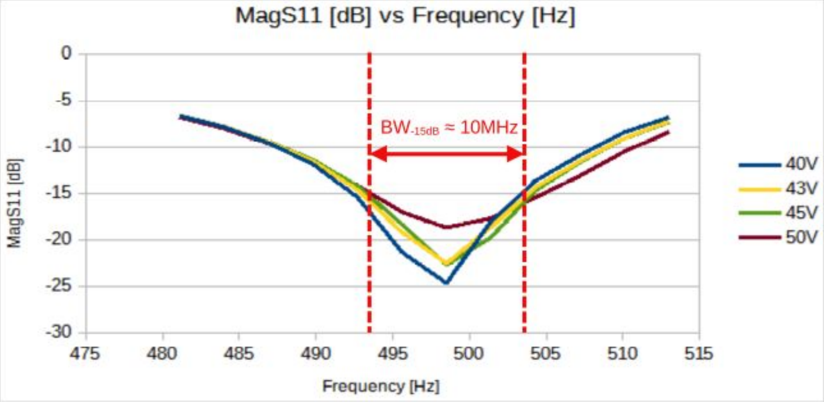


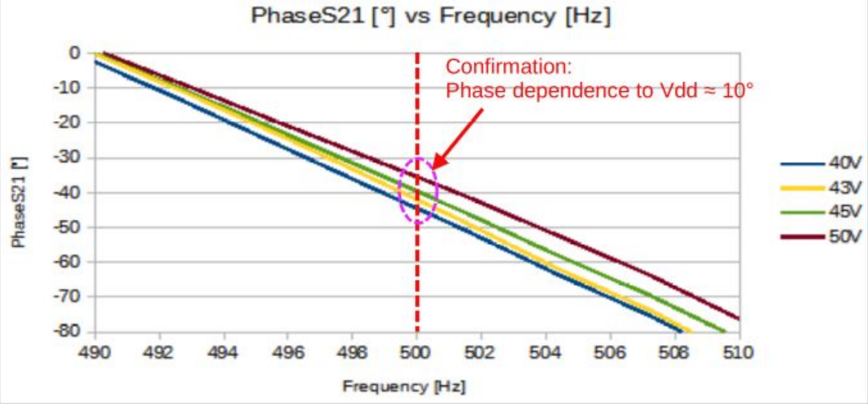


Storage Ring – Solid-state RF Station - RF Unit measurements

Vdd and Frequency sweep - 20220831, Freq=20-600MHz Pout@500MHz≈650W Vdd=43V Idd@500MHz≈24A







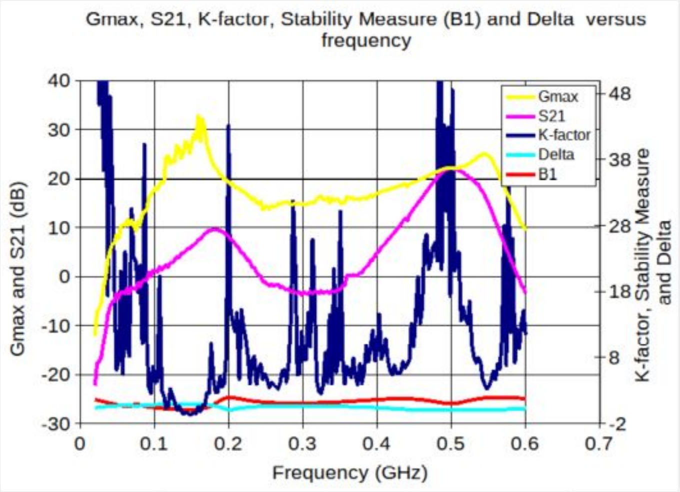
This results show that the RF Unit is easily optimizable for the best efficiency at the required RF output power.

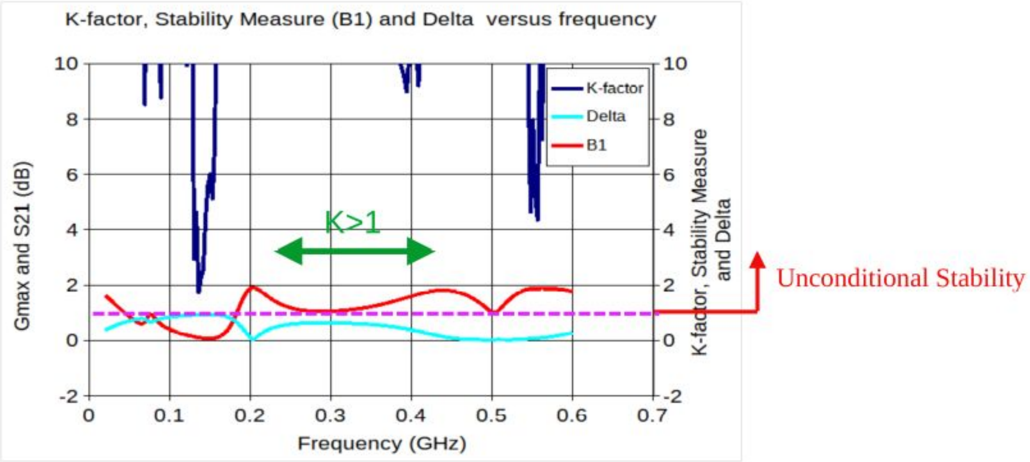
We expect the same performance to be presented by the final constructed RF stations.

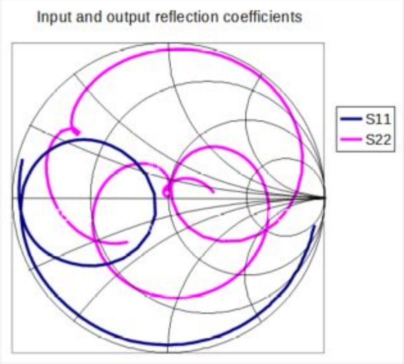
We expect that the final efficiency (wall plug to Rf output) will be greater than 60% after the complete RF system is optimized. Of course assuming that the losses of oder components of the system will stay under 5% at most.

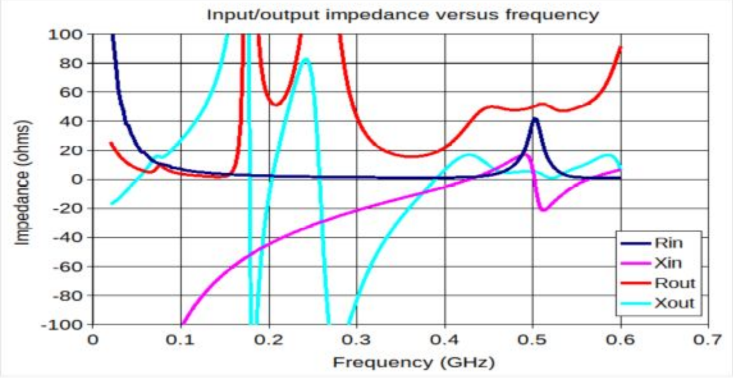
Storage Ring – Solid-state RF Station - RF Unit measurements

Stability - 20220815, Pout@500MHz=580W, Vdd=43V, Idd@500MHz=21.4A









Conclusions

We have presented a general view of the work beeing performed at the moment for the upgrade of the Swiss Light Source.

The storage ring cavities and RF stations are presently beeing commisioned. Some components may be slightly affected by supply chain issues but should not affect schedule of the project.

SLS2 (booster and storage ring) will be in operation purelly driven by solid-state amplifiers.

Due to the use of solid-state technology we expect a considerable improvement in efficiency of the complete accelerator system.