Lattice Correction using LOCO for the ThomX Storage Ring

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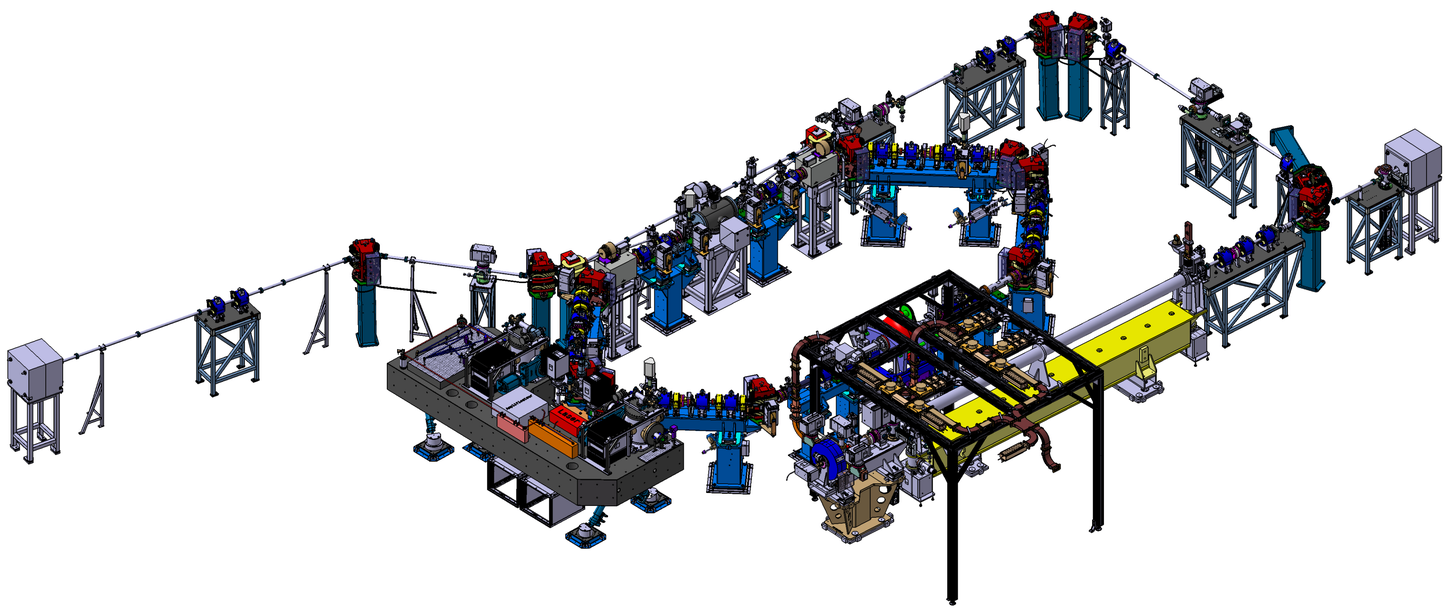
Introduction

ThomX is a project to build an accelerator based compact X-ray source in Orsay (France). At present, the ThomX machine is under construction.



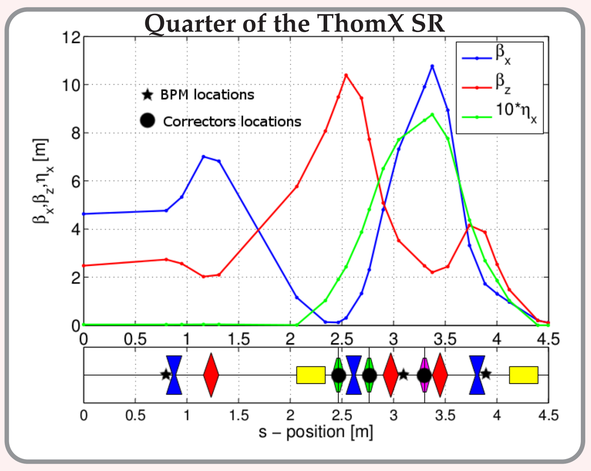
Parameter	Value	Units
Beam energy	50 – 70	MeV
Bunch charge	1	nC
Bunch length (rms)	20 – 30	ps
Circumference	18	m
Revolution Frequency	16.7	MHz
Current	16.7	mA
RF frequency / Harmonics	500 / 30	MHz
Momentum compaction	0.0125 – 0.025	
Betatron tunes	3.17 / 1.64	
Natural chromaticity	- 3.3 / -7	
Damping time, tr. / lg.	1 / 0.5	s
Repetition frequency	50	Hz
Beam size at IP (rms)	70	μ m

☞ **Broken symmetry of the SR optics (field, calibration and misalignment errors) ⇒ Resonant excitation ⇒ Strong effect on the beam dynamics and so the X-ray generation in the ring.**

☞ **To ensure a high flux X-ray production ⇒ Linear optics of the ThomX SR has to be measured and controlled.**

ThomX Storage Ring

- ThomX SR design is based on a DBA optics with a two-fold symmetry including 8 45° dipoles, 24 quadrupoles and 12 sextupoles.



LOCO algorithm

LOCO is a program analysing the measured ***Orbit Response Matrix (ORM)*** and matching the machine model. It is based on the χ^2 function minimization which is given by:

$$\chi^2 = \sum_{i,j} \frac{(M_{ij}^{mod} - M_{ij}^{meas})^2}{\sigma_i^2},$$

where M_{ij} are the ORMs and σ_i is the measured BPM noise level.

$$M_{ij} = \frac{\sqrt{\beta_i \beta_j}}{2 \sin \pi\nu_x} \cos(|\phi_i - \phi_j| - \pi\nu_x) + \frac{\eta_i \eta_j}{\alpha_c L_0} \text{ (hor.)}$$

$$M_{ij} = \frac{\sqrt{\beta_i \beta_j}}{2 \sin \pi\nu_z} \cos(|\phi_i - \phi_j| - \pi\nu_z) \text{ (vert.)}$$

Conclusions

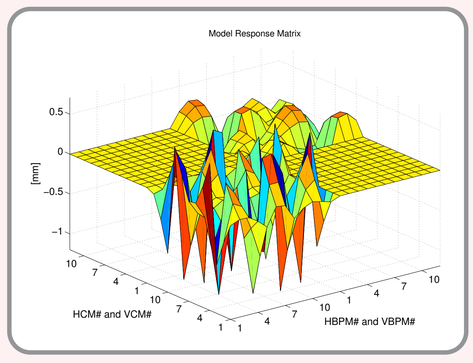
☞ This first study indicates that it is possible to apply the LOCO algorithm to

- restore the ThomX SR lattice symmetry
- get the correct tunes
- predict appropriate settings for the skew quadrupoles to reduce coupling and correct for the vertical dispersion.

☞ Dedicated routines to measure the ORM according to the limited 20 ms ThomX storage without damping to be develop.

Fitting results with LOCO

LOCO data preparation:

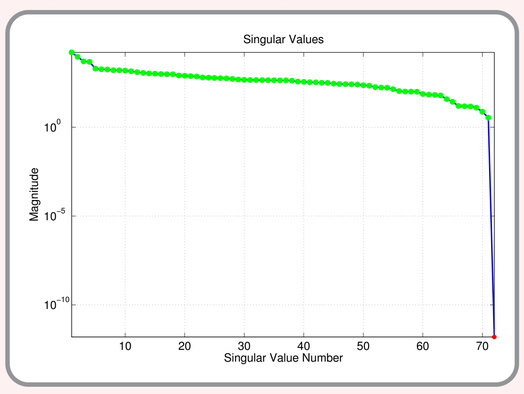


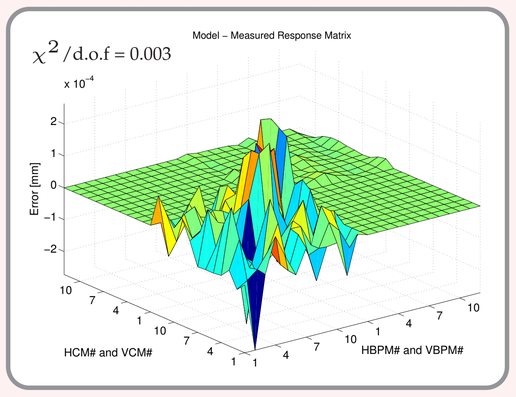
- All the simulations have been performed by using ***MML and AT*** softwares with the ***LOCO code integrated in Matlab***.
- To perform the linear lattice correction ⇒ LOCO requires *1) measured ORM 2) measured dispersion 3) BPM noise level*.
- ThomX SR: **12 BPMs** (dualplane) and **12 correctors** (dualplane) producing **576 data points** (600 if dispersion is included).
- The nominal fitting parameters: quadrupole strengths, BPM and corrector gains which gives **72 fitting parameters**.

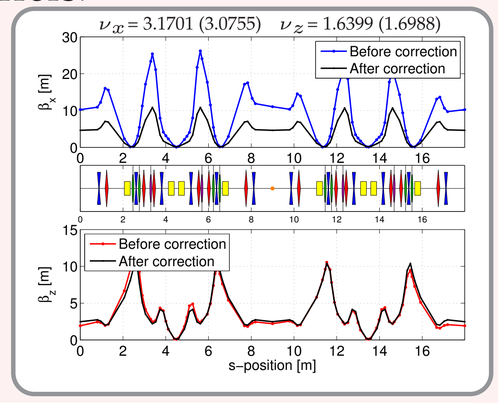
☞ *Introduced errors to the nominal lattice of the ThomX SR:* **1% error of the quadrupole strength, 5% error of the BPMs and correctors gains** and **BPMs rms noise level** at the level of **1 μm**.

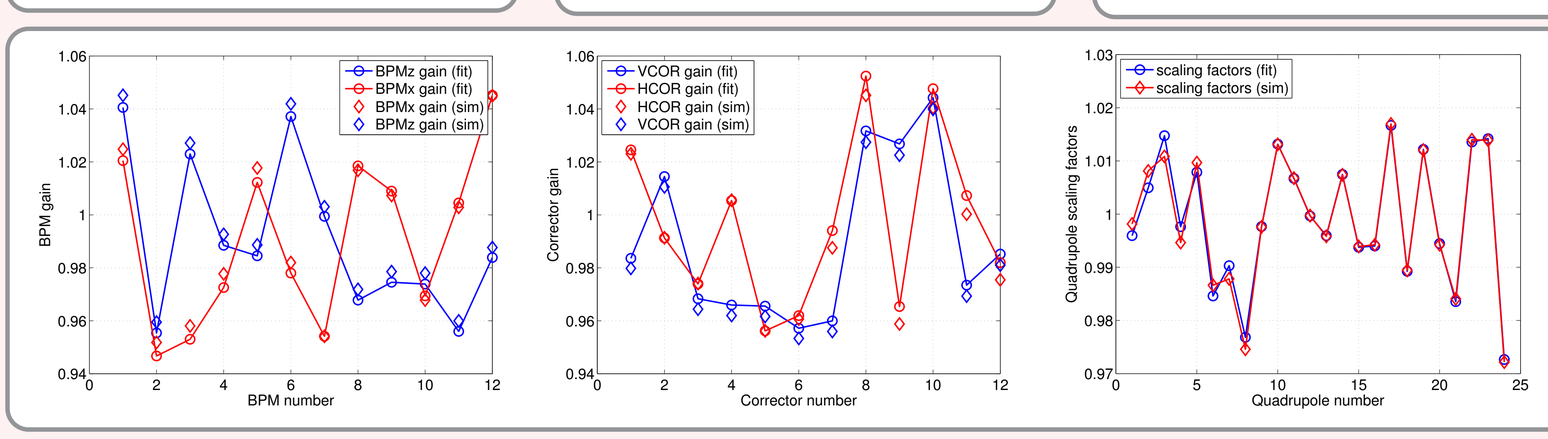
ORM fit results:

- Starting with a model having distributed errors, it was possible to establish a nominal lattice of the ThomX SR and find the introduced calibration and field errors:

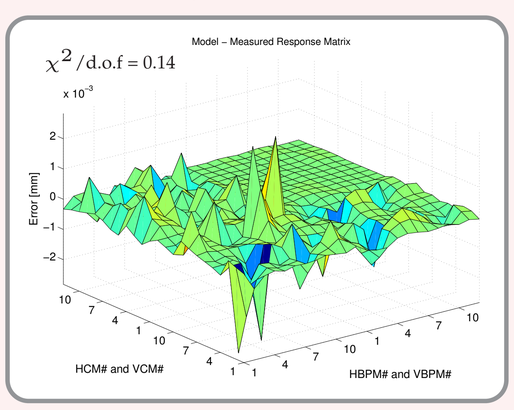


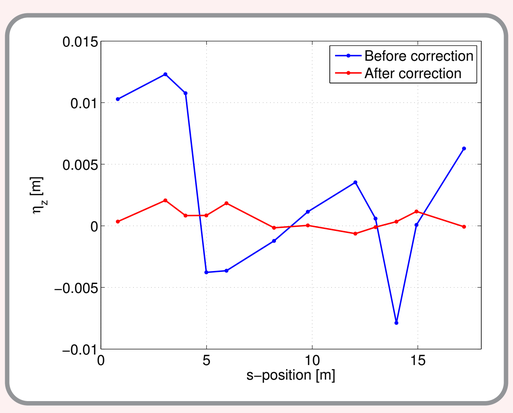






- **8 ghost skew quadrupoles** (two per arc) have been introduced in the sextupoles to investigate a possibility of **linear coupling** and **vertical dispersion** correction.





- *Introduced error:* a **tilt of 1 mrad rms** applied to all quadrupoles.
- Required strength of the skew quadrupole predicted by the LOCO is ∼0.1% of the ring quadrupole strength.