Simulation and Optimization of the Transport Beamline for the NovoFEL RF Gun

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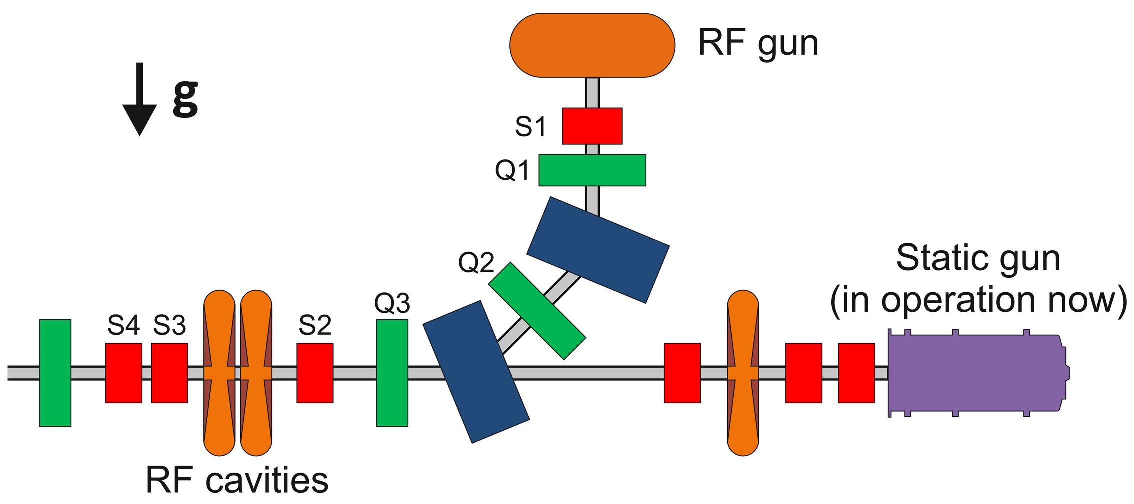
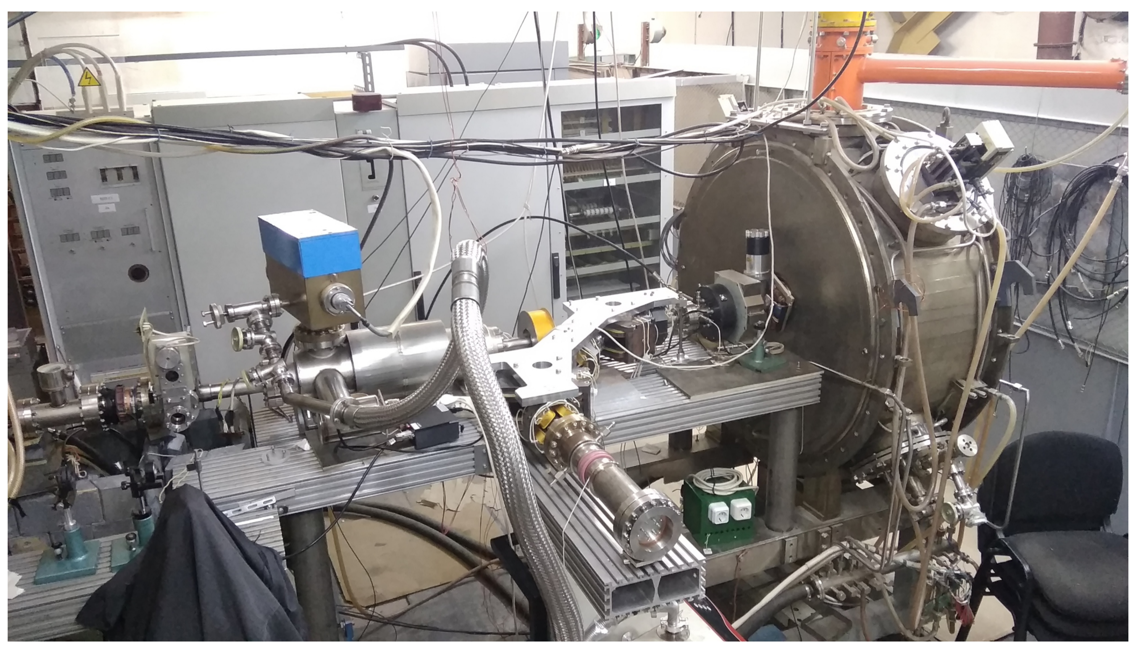
ABSTRACT

A new low-frequency CW RF gun was developed and tested at Budker INP recently. We plan to use it to upgrade the ERL of the Novosibirsk FEL facility. It will allow increasing the average beam current (due to higher beam repetition rate) and thus increasing the average radiation power. The transport beamline for the RF gun uses the ninety-degree achromatic bend. It is designed in a way that keeps an option to operate with the old electrostatic gun as well. Due to the low beam energy (290 keV) the beam dynamics is strongly influenced by space-charge forces. The paper describes results of simulation and optimization of the RF gun transport beamline. Space-charge forces were taken into account with the code ASTRA. In addition, the RF gun output beam parameters were measured for various RF gun emission phases. These experiments were simulated, and the results were compared. The resulting beam parameters meets requirements of the Novosibirsk FEL facility ERL.

RF GUN BEAMLINE



A scheme of the NovoFEL injector with the new RF gun: red – solenoids, green – quadrupoles.

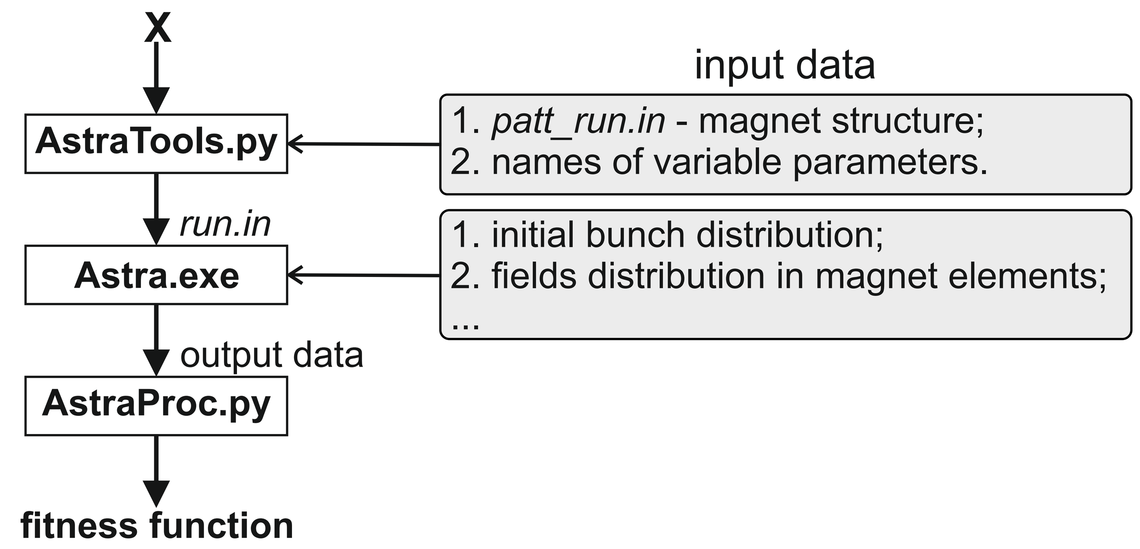


A view of RF gun stand. 90° bend is assembled.

Basic RF Gun Parameters

Parameter	Value	Unit
Average Current	≤ 100	mA
Electron Energy	240-300	keV
Bunch Charge	≤ 2.0	nC
Bunch Length (FWHM)	1.0	ns
Peak Current	15	A
Beam repetition rate	0.002 – 90.2	MHz

OPTIMIZATION

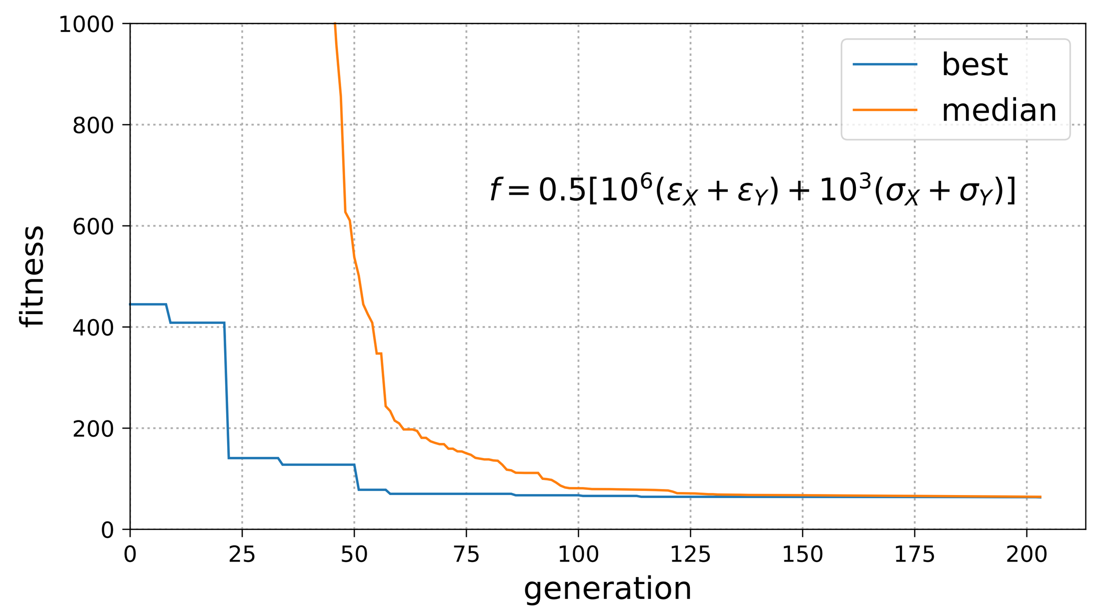


Python scripts make a simulation of magnet optics regime as a calculation fitness function

Used algorithms of optimization:
- differential evolution (DE) algorithm;
- Nelder–Mead method.

Variable parameters:
- **S1-S2** currents that are in range 0...10A;
- **Q1** and **Q3** currents that are in range -3...3A.

Dependent parameters:
- **Q2** current - to get an achromatic bend;
- **S3-S4** currents - to suppress coupling of transverse betatron oscillations.

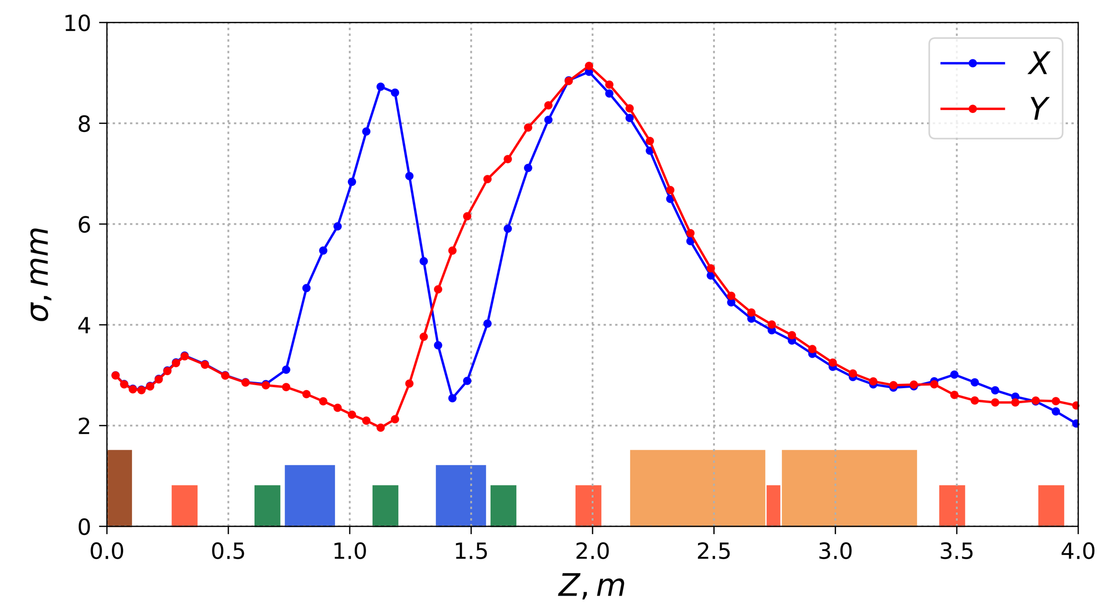


The process of optimization with DE algorithm. $\varepsilon_{X,Y}$ – normalized emittance and $\sigma_{X,Y}$ – rms beam size (both in meters)

RESULTS

A cooling aperture at the center of the bend was considered so as to decrease bunch energy distribution. So, an optimal regime with beam propagation of 81% and normalized transverse emittances of 27 mm·mrad was achieved.

Results will be applied when the beamline is commissioned.

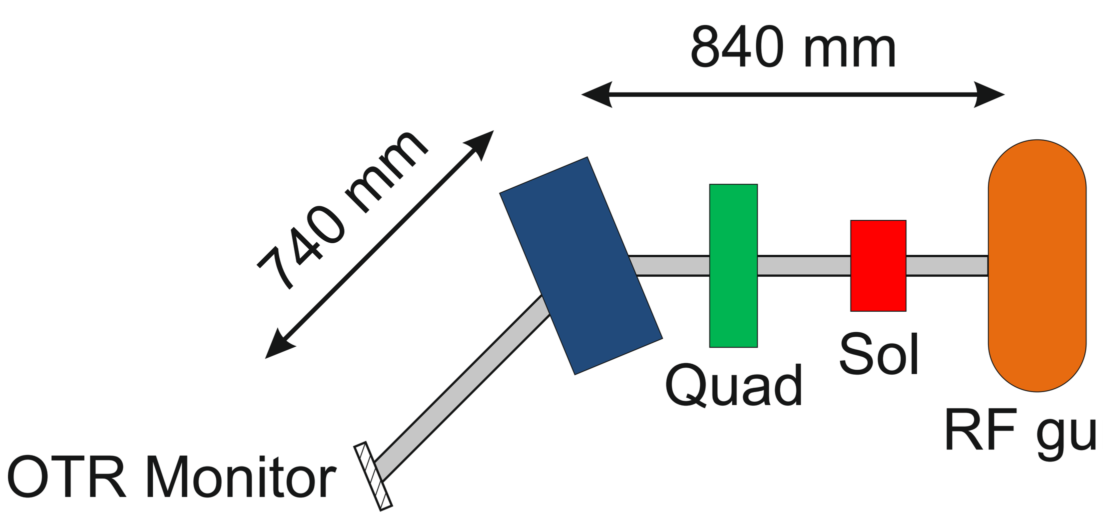


The optimized beam sizes for the RF gun beamline.

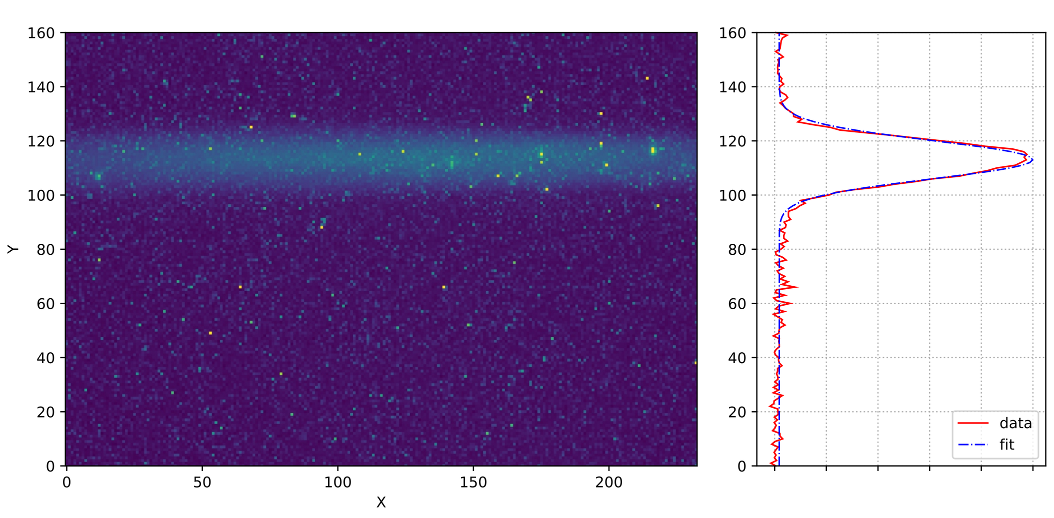
Optimized Regime: Electron Beam Parameters at the Output of RF Gun Beamline

Parameter	X	Y
Propagation	0.81	
Normalized Emittance, mm·mrad	27.6	27.0
Average Local Norm. Emit., mm·mrad	13	20
Beta Function (β), m	0.39	0.82
Alpha Function (α)	-0.092	0.017
Longitudinal Size, ps	42	
Kinetic Energy of Electrons, MeV	1.356	
Energy distribution, σ_p/p_0	0.008	

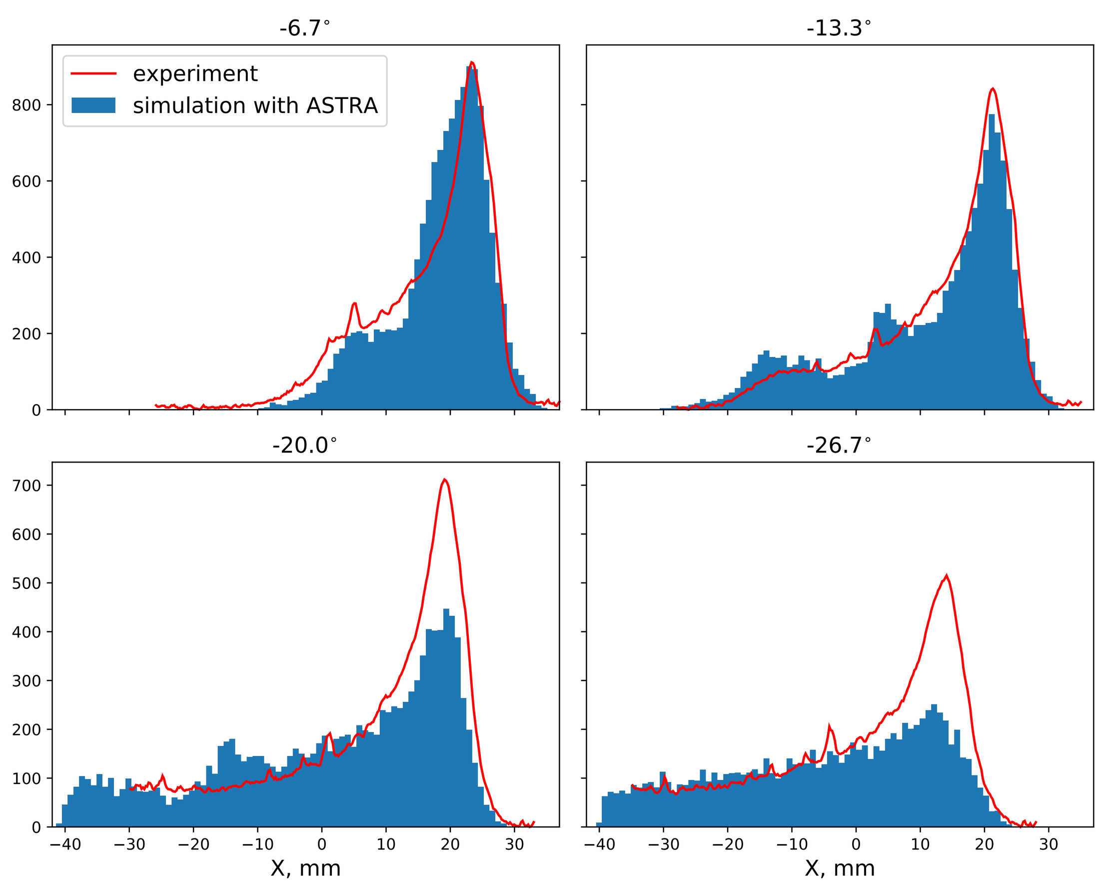
MEASUREMENTS OF BEAM PARAMETERS



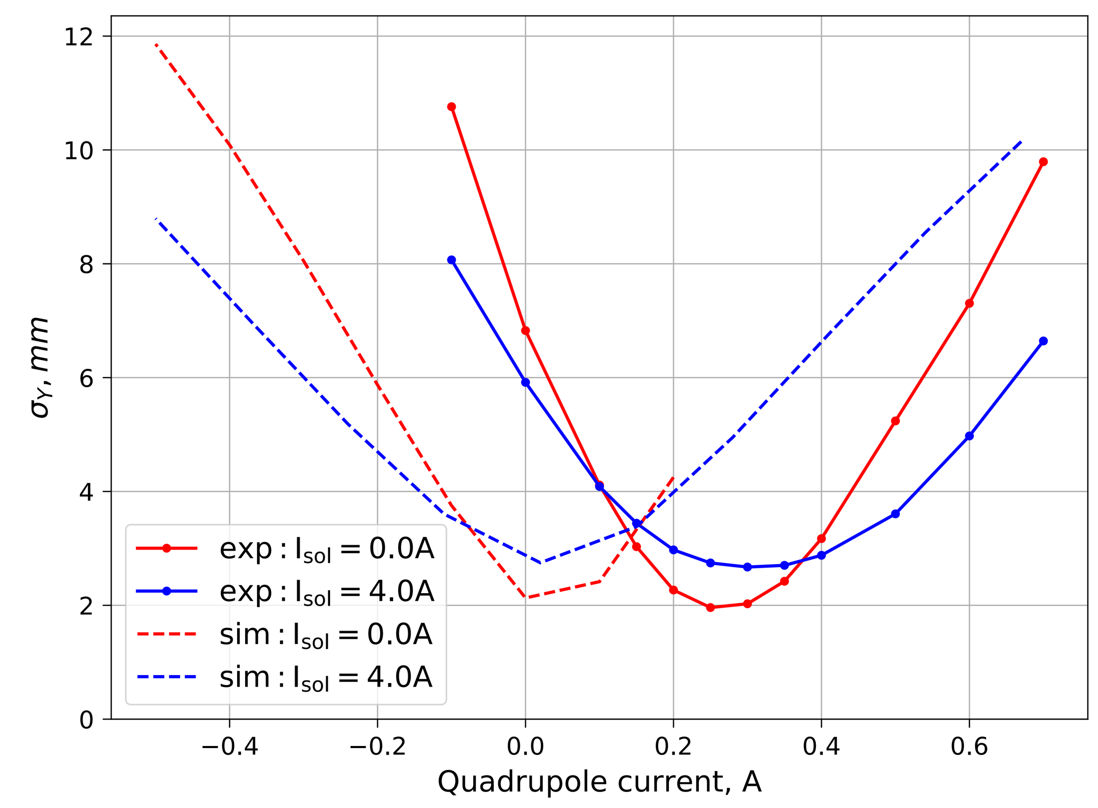
The scheme of the RF gun test stand



The example of beam image in a quadrupole strength variation experiment



Transverse horizontal beam density distribution at the monitor for several the RF gun injection phases (0° - the phase of the maximum acceleration).



Dependence of vertical beam size at the monitor on quadrupole strength for two currents of solenoid (measurements and simulation).

39th International Free-Electron Laser Conference,
26-30 August 2019, Hamburg, Germany

THP027