Studies on Integrated Optics Design for Diffraction Limited Light Sources

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Thanks to the Accelerator Physics group in Diamond

Outline

- Introduction of Diamond and Diamond upgrade.
- E2S (Electron to sample)

  1. Characterization of I13-coherence branch in E2S

  2. Beamline Optimiser (E2S-SRW optimiser and E2S-SHADOW optimiser)

- Conclusion and future work

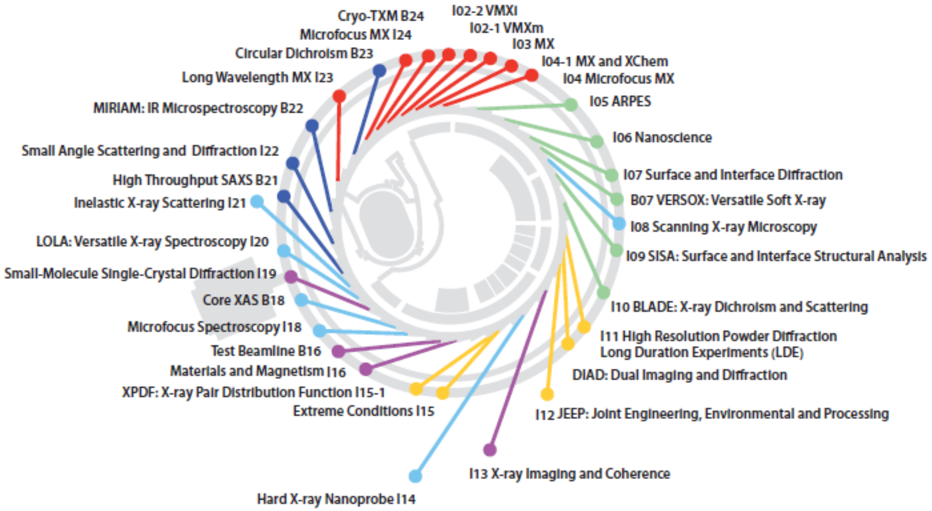
Diamond light source

Beam energy: 3 GeV
Circumference: 561.571 m
Current: 300 mA
Natural emittance: 2.7 nm.rad

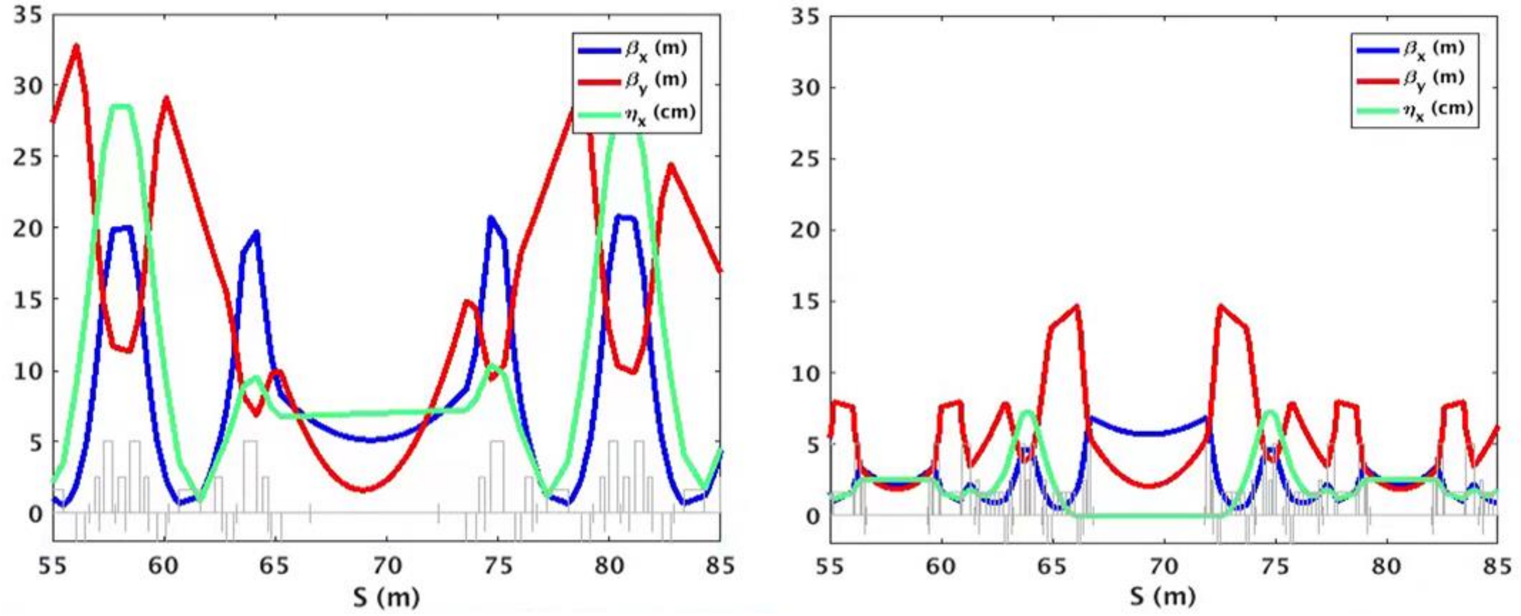
2700 pm.rad (Diamond I)

↓

160pm.rad (Diamond II)



Diamond light source upgrade



Twiss parameters in same position with the VMX lattice(left) for present Diamond and the 6-HMBA lattice(right) for Diamond-II.[1]

Double Bend Achromat (DBA) cells → 6-Hybrid Multi-Bend Achromat (6-HMBA)

[1] M. Apollonio et al.," Evaluation the impact of Diamond-II possible lattices on beamlines", Proc. IPAC 2018, 2018

Electron and photon beams optimisation

John Adams Institute for Accelerator Science

The design and optimisation of the electron dynamics and X-ray beam production consists of several steps usually separated and belonging to different groups.

Integrated design electron to sample (E2S)

Elegant: Accelerator simulation code developed at the Advanced Photon Source (APS) for electron beam tracking and dynamics.

Accelerator

Electron beam parameters →

SRW: A physical optics computer code for calculation of detailed characteristics of Synchrotron Radiation (SR) .

Photons optics

→

Flux
Brightness
Tuning curves
Power density
Beam-spot intensities

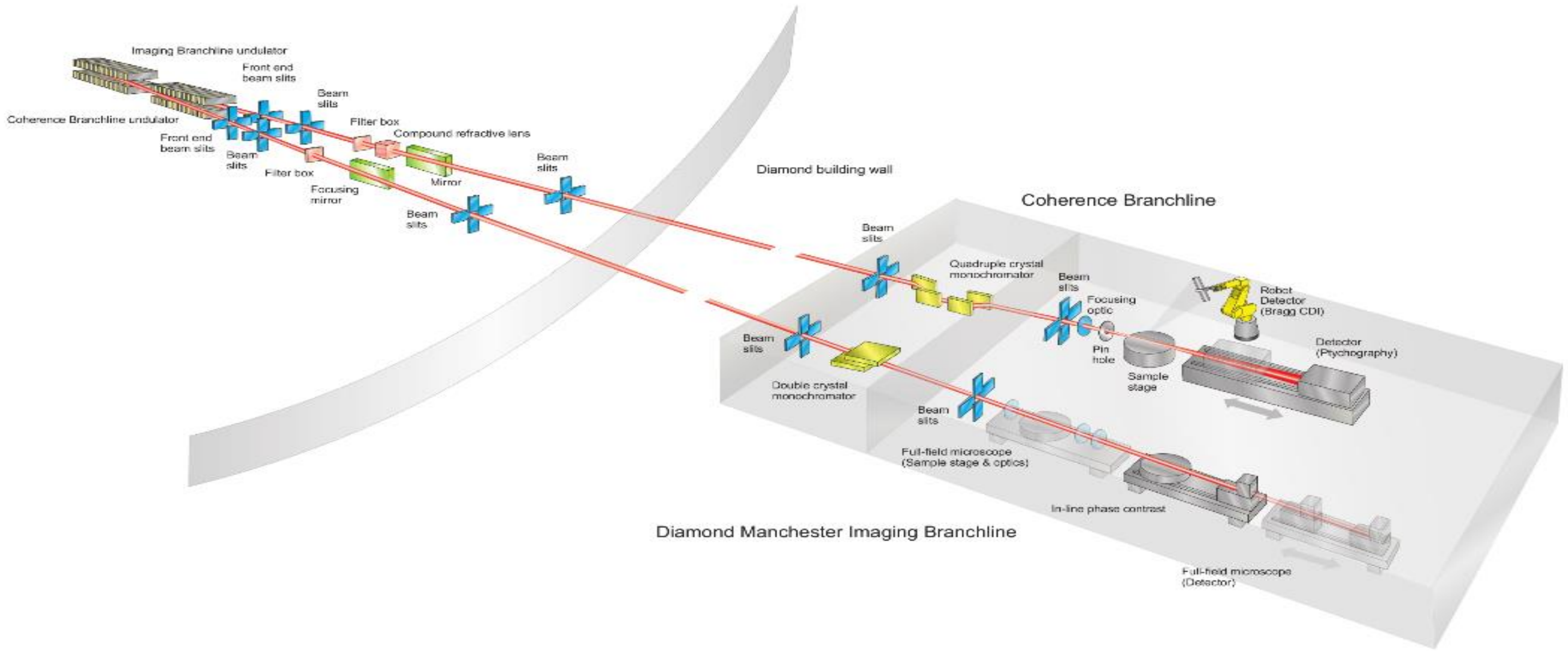
X-ray properties

The goal is to integrate the design of electron and photons source to find the best trade off between accelerator and photon optics performance and guarantee the production of photon beam with best properties.

Beamline Example

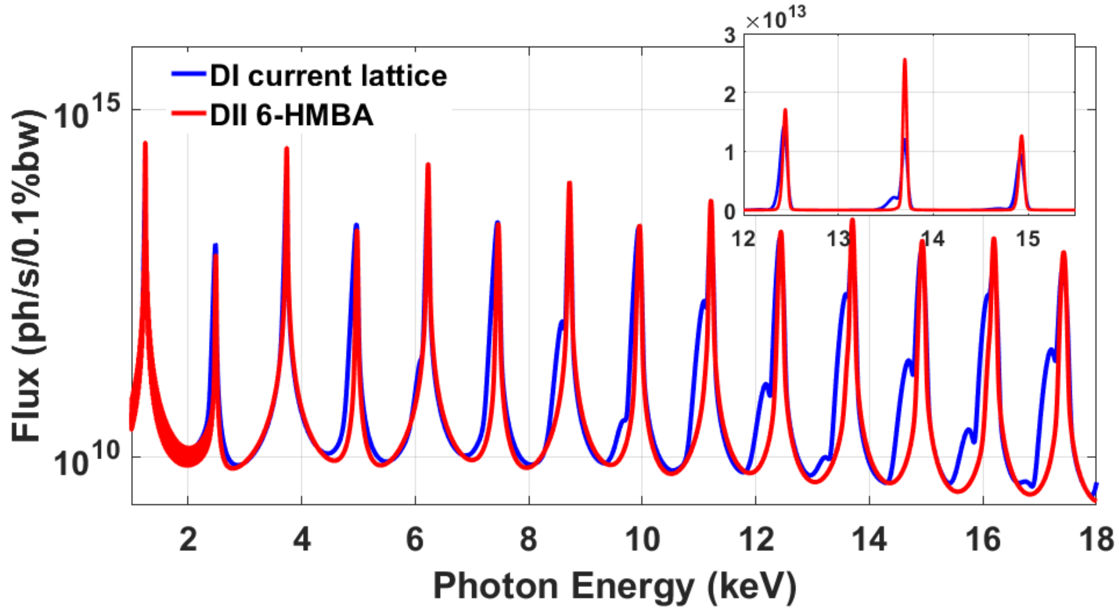
I13 beamline

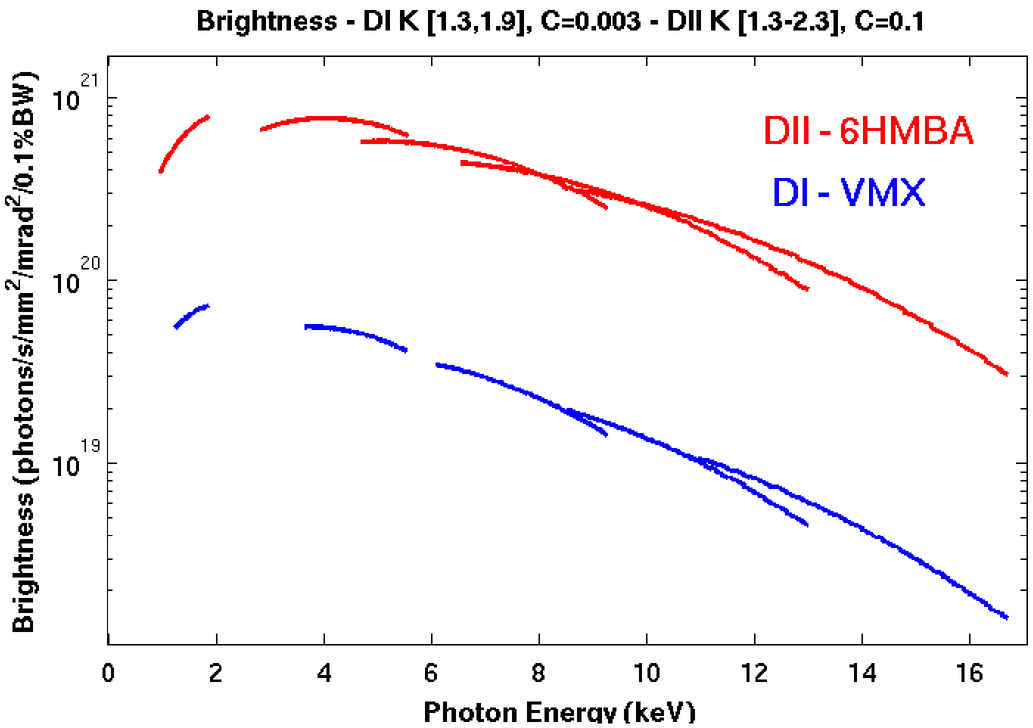
- The longest beamline in Diamond with 250m.
- Two branches provide complementary X-ray imaging techniques to support a broad range of scientific users.



Source: http://www.diamond.ac.uk

Characterization of I13-coherence branch in E2S

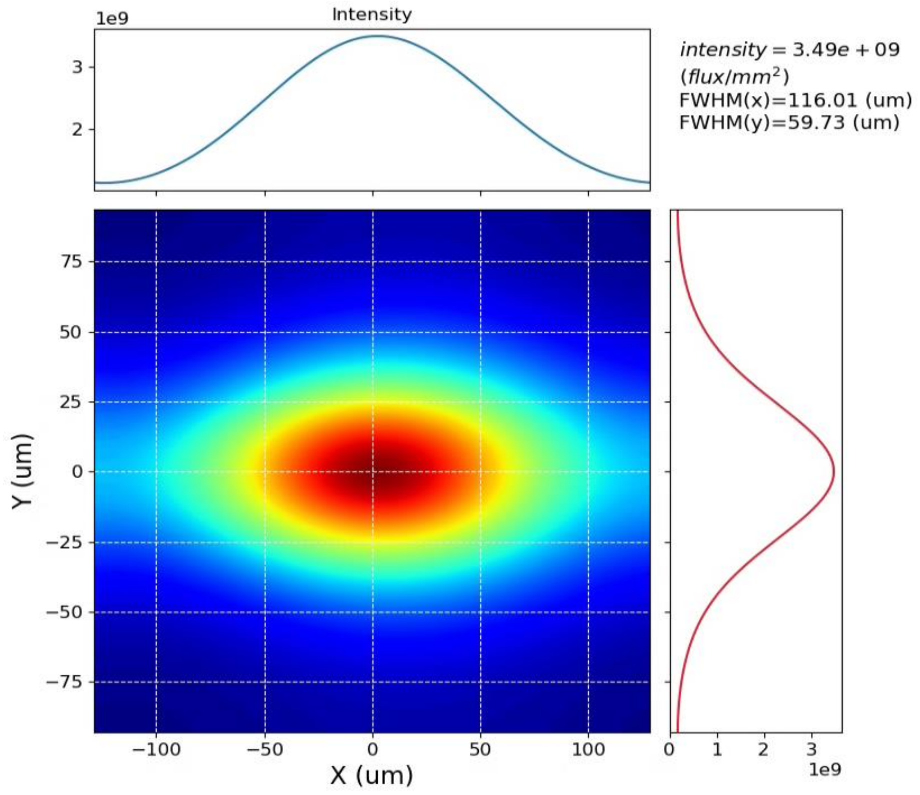


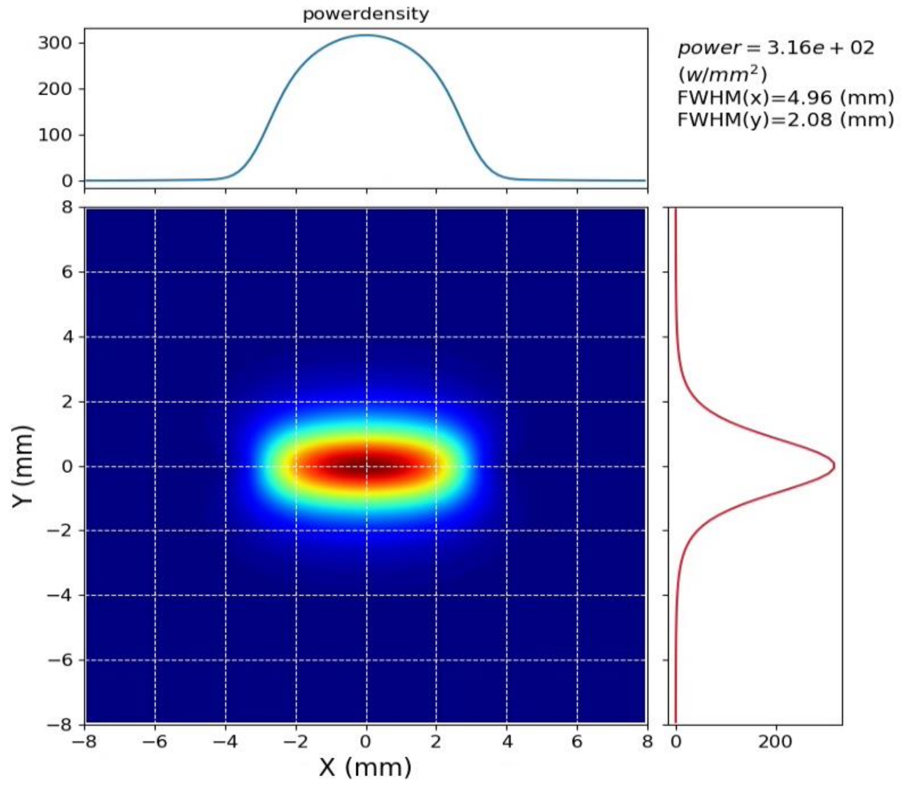


Partial flux and brightness at I13-coherence in Diamond I (blue) with the present VMX Twiss parameters at straight 13 and Diamond II (red) with the new ones for the 6-HMBA case design for Diamond-II[1]

[1] M. Apollonio et al.," Evaluation the impact of Diamond-II possible lattices on beamlines", Proc. IPAC 2018, 2018.

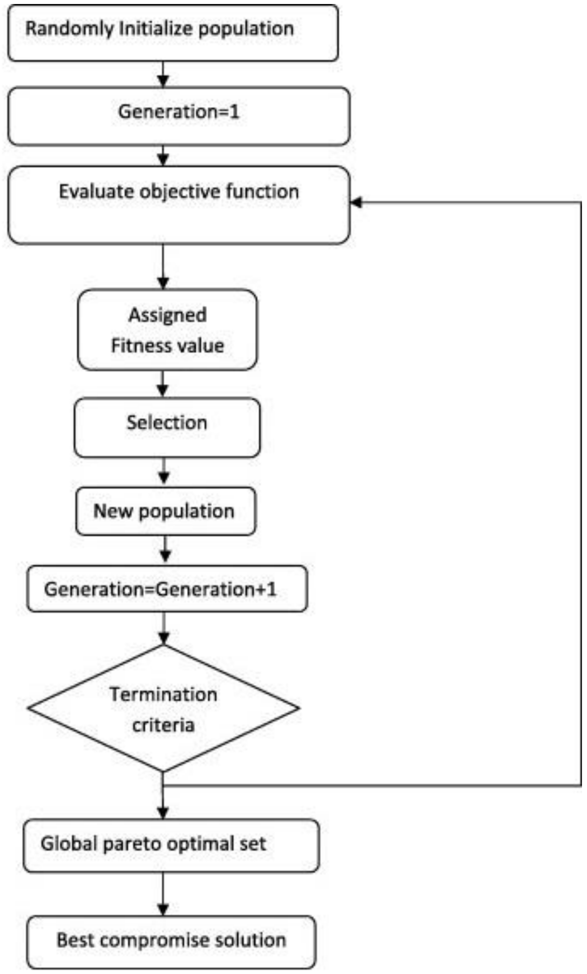
Characterization of I13-coherence branch in E2S





(Left)Beam intensity distribution in X, Y position in I13 coherence branch, after optic elements CRL, mirror and quadruple crystal monochromator. (Right) Power density in I13 coherence branch at position 11.55m from source.

Beamline Optimiser



Flow chart of Genetic Algorithm[1]

Genetic Algorithm implements the principles of biological evolution to optimise a multidimensional problem.

Optimiser input

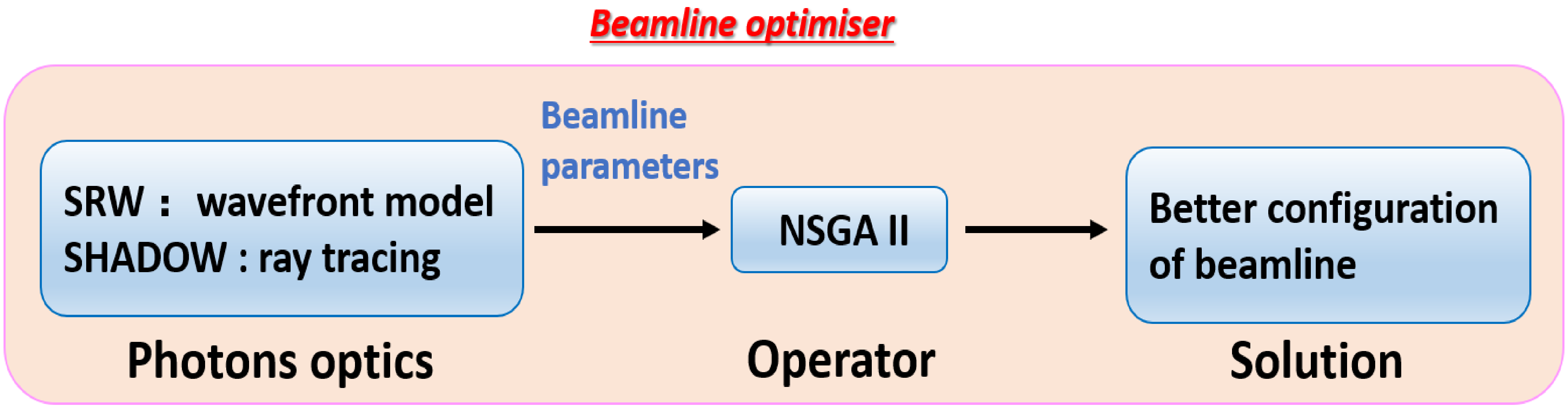
Initial population: current beamline and some copies.
Individuals: beamlines with changed parameters.
Objectives: Performances in beamlines.

Iterations

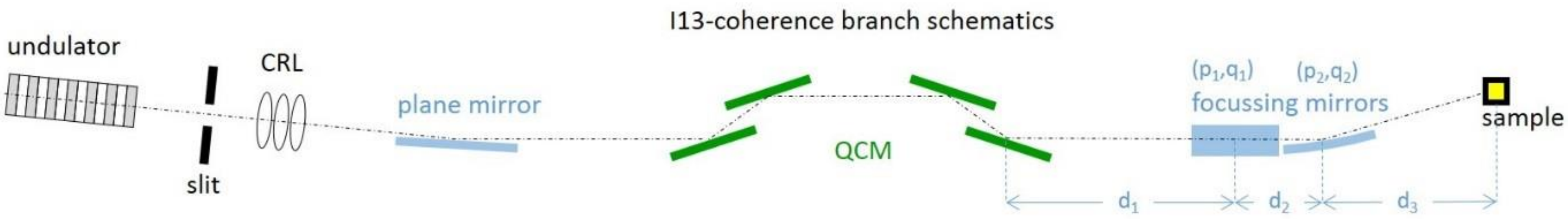
Best solutions of beamlines

[1]J.Preetha Roselyn et al. Multi-Objective Genetic Algorithm for voltage stability enhancement using rescheduling and FACTS devices. Ain Shams Engineering Journal (2014) 5, 789–801

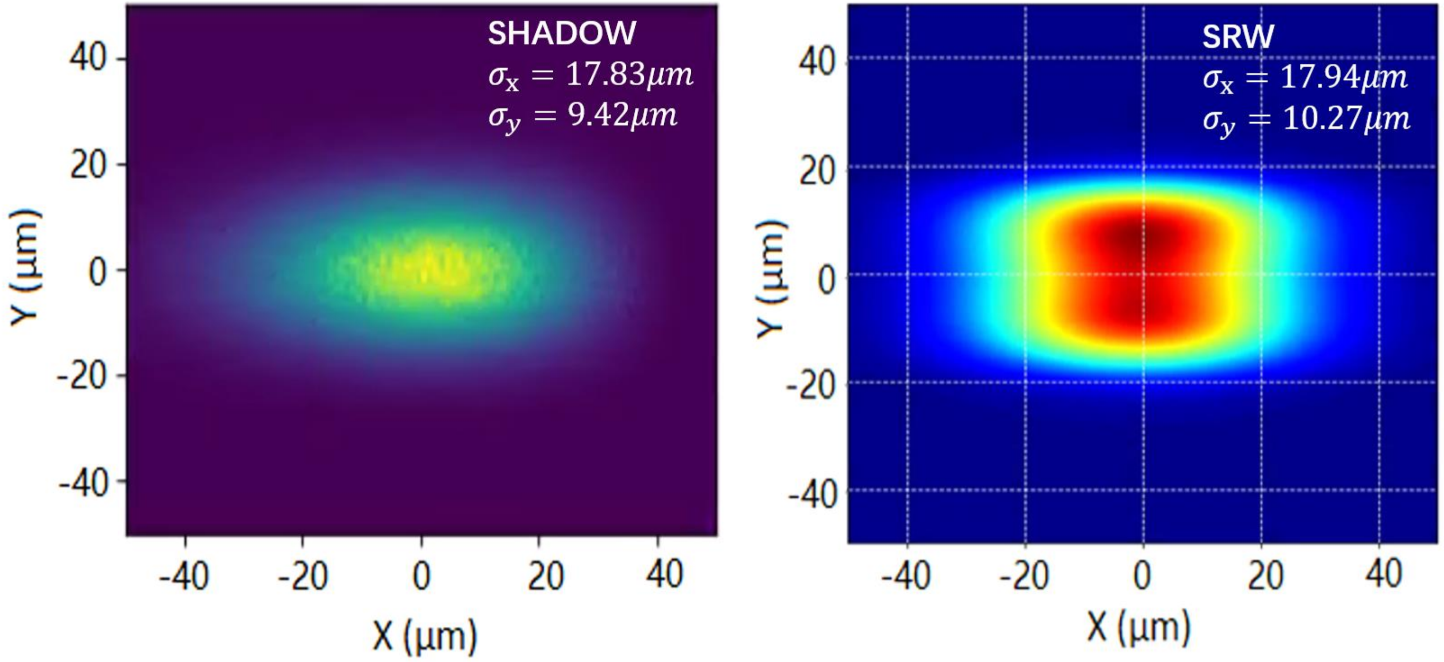
Beamline Optimiser



Beamline Optimisation

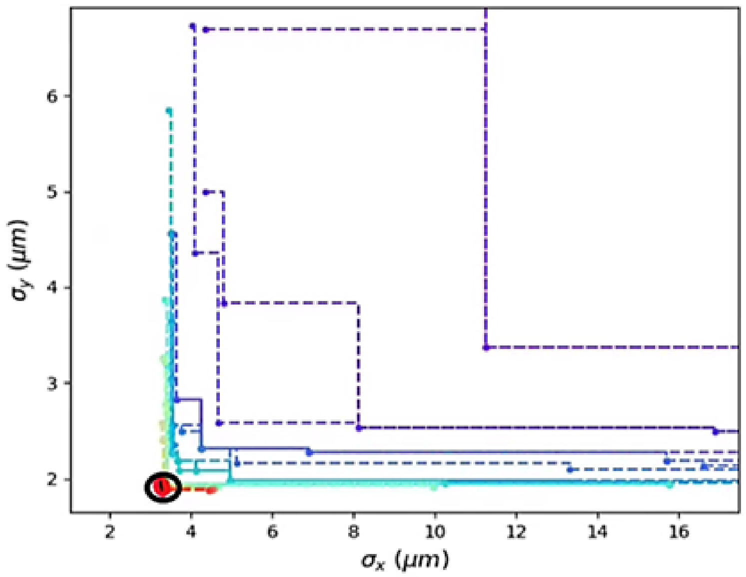


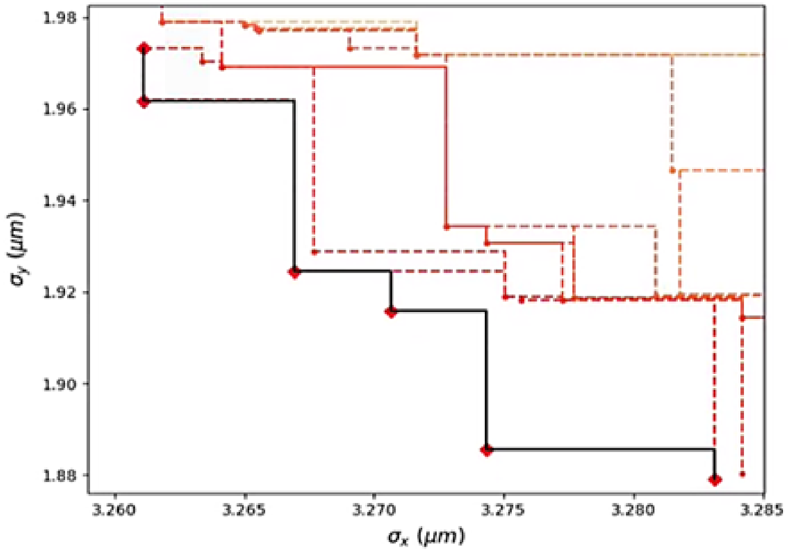
Seven parameters (shown in this figure) are chosen to optimise the performance of this beamline.



Beam spot at sample of I13 coherence branch with baseline configuration calculated by SHADOW (left) and SRW (right).

Beamline Optimisation



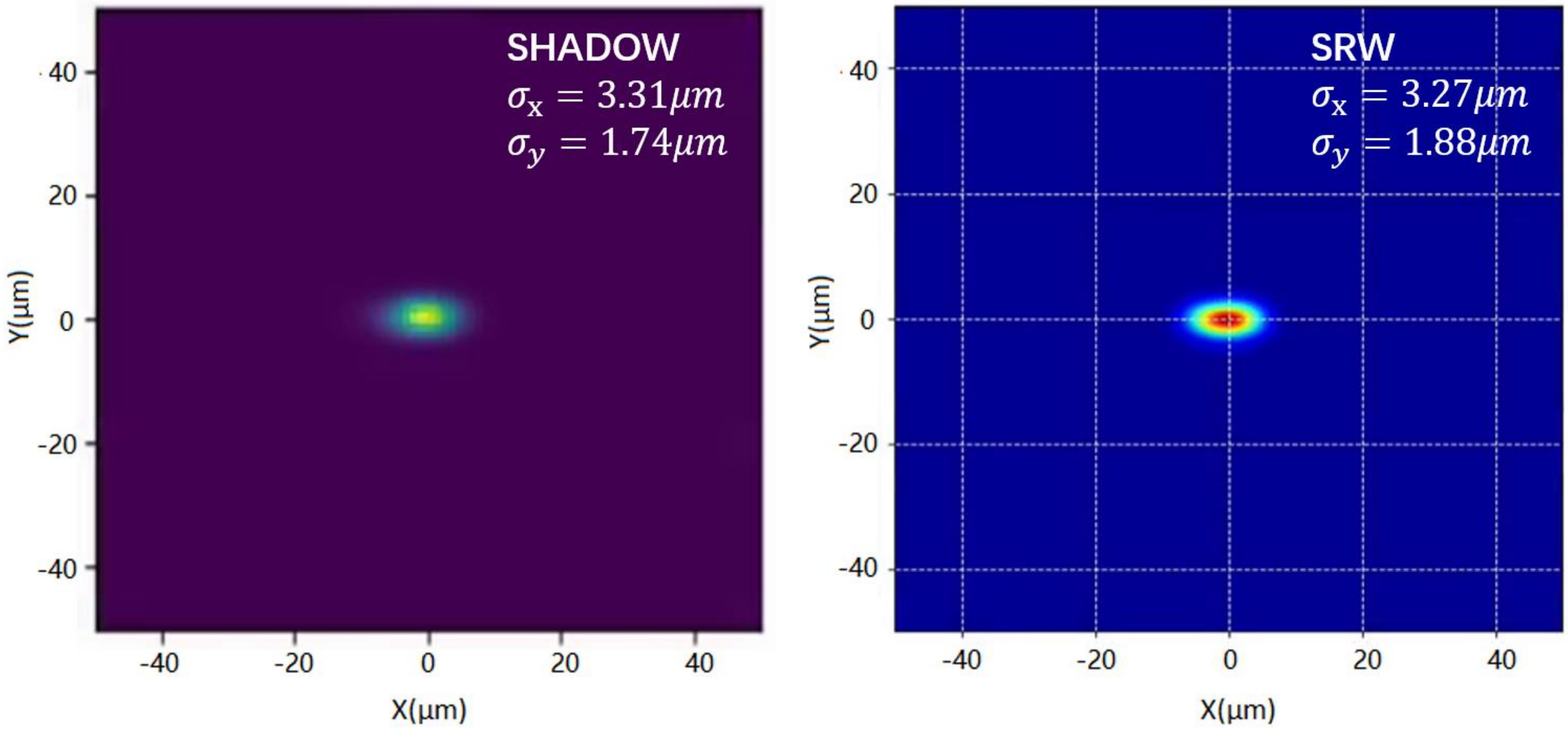


Left: Convergence of the fronts from E2S-SRW optimiser. Right: zoom-in of dark circle part.

	d_1(m)	d_2(m)	d_3(m)	p_1(m)	q_1(m)	p_2(m)	q_2(m)	σ_x(μm)	σ_y(μm)	I(flux/mm^2)
baseline	10	2.2	5.5	30.9	9.1	33.1	6.9	17.94	10.27	2.68e+17
Generation 8	9.00	1.87	5.06	31.13	8.99	32.33	6.02	8.11	2.53	3.11e+18
Generation 38	11.11	1.50	5.00	34.31	7.96	31.69	5.76	3.44	1.91	9.54e+18
Generation 50	11.09	1.33	5.00	30.65	7.93	32.50	5.74	3.27	1.88	9.94e+18

Parameters used for the 7D genetic optimisation, together with the objectives during several phases of NSGA evolution towards a beamline with a very small image at the sample plane.

Beamline Optimisation



Beam spot at sample position after E2S-SHADOW optimisation (left) and E2S-SRW optimisation (right).

Beamline Optimisation

For the next step, the accelerator optics can be taken into account to an optimisation. Accelerator optics are entirely encoded into the Twiss parameters.

1. Assume the beamline parameters being locked to specific values, we study how variation of the optics will translate to variation on the beam spot from the baseline beamline.

2. A general case where both the Twiss and the beamline parameters are allowed to vary.

Further considerations needed to do this kind of optimisations : how the selected set of Twiss parameters reflects locally and globally on the particle accelerator lattice, how this affect its non-linear dynamics.

This can be explored in future work.

Conclusion and future work

- E2S can build the bridge from electron dynamics to photon dynamics, it would be a valuable tool for the design and upgrade of synchrotron radiation light sources in future.

- Future work:

In order to obtain a more practical optimisation, the constraints of the optical elements should therefore be supplemented in the optimiser.

An optimisation loop to optimise electron dynamics and photon dynamics together to obtain a more reliable solution.

References

[1] M. Apollonio et al.," Evaluation the impact of Diamond-II possible lattices on beamlines", Proc. IPAC 2018, 2018.

[2] http://www.diamond.ac.uk.

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[5] M. Borland, "elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation", Advanced Photon Source LS-287, (2000).

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[10] T. Tanaka and H. Kitamura, J. Synchrotron Radiat. 8, 1221(2001).

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Thanks for your attention!