Helmholtz Investigator Group

Beam Dynamics and Collective Effects in the Generation and Propagation of Structured Beams for Advanced Accelerator-based Radiotherapy

General information:

Applicant

Dr. Miriam Brosi, Lund University, MAX IV Laboratory, Lund, Sweden, 34, female, defense: 31.01.2020

Assignment KIT-division

Division V

Host Institute and contact person at KIT

Institute for Beam Physics and Technology (IBPT), Prof. Dr. Anke-Susanne Müller

Field of study and Helmholtz-program

Helmholtz program: Matter and Technology, Accelerator Research and Development (ARD)

Description of international experience such as position program, purpose, duration

Guest scientist at Laboratory of Physics of Lasers, Atoms and Molecules (PhLAM) at the Université de Lille, France, 2 month between 10/2021-12/2022: I worked on a detailed comparison of two Vlasov-Fokker-Planck solver simulation codes for the propagation of particle distributions under the influence of collective effects with the french national synchrotron SOLEIL and KARA at KIT as example cases.

Postdoctoral researcher at MAX IV laboratory, Lund University, Sweden, > 2 years, since 01/2022: In the accelerator development group, I focus on theoretical and experimental studies of collective effects in the ultra-low emittance ring of the 4th generation synchrotron light source at MAX IV.

Description of leadership experience

During my PhD, I supervised and co-supervised one bachelor and three master students, working on measurement data analysis, simulations on the influence of arbitrary impedances on beam dynamics, data analysis based on machine learning and fast, single shot measurement methods respectively. Furthermore, during three summer semesters, I was the tutor ("Übungsleiter") for bi-weekly exercises for students attending the lectures on accelerator physics. Over four years, I was involved in organizing and supervising the accompanying simulation course and practical hands-on course on the accelerator.
As postdoctoral researcher, I lead the project for the replacement of the main storage ring magnet power-supplies, supported by the chief electrical engineer. I coordinated the efforts, acted as main contact to potential suppliers and wrote the specification for the procurement of the optimized power-supplies, including calculations on the stability tolerances and their effects on operation. Furthermore, I scientifically advised a PhD student on their investigation of additional impedances added to the accelerator and the resulting influence on the studied collective effects, who will defend his thesis in May this year.
Besides my main research as postdoc at MAX IV, I have lead the efforts to establish a new time-correlated single-photon counting setup as standard fill pattern diagnostic for the accelerator operation. This includes currently the supervision of a bachelor student with the task to extend the setup to also function as a bunch shape measurement method.

Information about the Project:

Abstract / Intent/ Goal

*<Please describe planned measures, future viability/sustainability of the topic, viability of the cooperation>*ADD FIRST SENTENCE: THIS PROJECT WILL….goal, by doing ….new method….
This is of critical importance to Helmholtz….Matter and technology….
What will be realized….with the goal to…change world
KIT best possible conditions as…..IBPT and Health-tech Center…..and close proximity and cooperation with Heidelberg for Cancer…

Particle accelerators play a vital role in a multitude of scientific fields such as the field of accelerator-based radiotherapy (RT). Both, accelerator physics and accelerator-based RT, have become highly complex where new developments push the understanding and the technological limits towards increasingly extreme beam properties. In electron accelerators, this includes ultra-short, high intensity pulses in linear accelerators and transversely narrow pulses in ultra-low emittance synchrotron light sources. These conditions lead to strong effects caused by the coexistence of many particles in the densely populated pulses, summarized under the term collective effects. In RT, the current development of two advanced approaches pushes in the same direction: FLASH RT is based on the delivery of very high doses in short pulses and Microbeam RT focuses on spatially fractionated beams. The new beam properties go beyond the prediction and beam diagnostic capabilities in conventional RT. This requires to push the understanding of the involved complex beam dynamics and collective effects. With my proposed project, I therefore aim at improving the understanding, predictability and control of the accelerator-based electron beams involved in FLASH and Microbeam RT and assess applicable detection methods. The entry point will be to extend the research on collective effects in accelerators to cover the beam properties required for FLASH and Microbeam RT, profiting from my expertise in this field. Subsequently, this project will expand the study beyond the particle accelerator into the beam-matter interaction up to the target tissue, investigating the influence of collective effects during the transport which up until now was sparsely studied. Based on these studies, the effective relation of input particle distribution to the dose distribution on target will be explored. This enables, the attempt to solve the inverse problem, i.e. determining the required input distribution for a desired dose distribution on target. First tests of targeted beam shaping will conducted within this project. With this kind of control, the outcome of the project will be a significant contribution to FLASH and Microbeam RT as well as to the general advancement of accelerator physics. more on why helpful acc …

Formal and Scientific Requirements (short)

<Presentation of a recognizable work plan, potential intermediate steps, presentation of the envisioned cooperation and potential communication structures>

work plan

The work plan consists of three work packages, with WP A and WP B running mostly in parallel and WP C building on the out come of the first two.

***WP A* - Complex beam dynamics and collective effects**

In WP A the complex beam dynamics of beam with significantly more…extreme properties for RT will be studied. Influence of collective effects investigated within the accelerator and extended to the beam matter interaction. Where they are not considered until now as unimportant for conventional RT. Extending models to include collective effects and not only consider single particle effects…

Output is a start to end simulation including beam dynamics and beam-matter interaction.

All based on my experience with collective effects and different simulation methods thereof. …

WP B - Systematic investigation on temporal and spatial pulse shape dependence of detection mechanisms and diagnostic tools

WP B will address the diagnostic required for the temporal and spatially structured beams. In accelerator and outside, and dose measurement, which was seen do be ??unreliable?? for the high dose rates in electron FLASH RT ….also 2D diagnostic for spatially structured beam,

test bed/benchmark calibration factors… and extend tests to even shorter pulses….

My experience with fast diagnostics helps…

WP C - Beam modulation and beam shaping

Explore …possibilities to shape beam spatially and temporally (e.g. spatial light modulator)

observe evolution of shape during transport, based on simulation tool from WP A and diagnostics from WP B

solve inverse problem, Investigation of methods and algorithms to calculate the required initial beam distribution from a desired beam shape on target

test generating custom distributions on target (by compensating or considering effects during transport…

cooperation

communication structures

Financial plan

The work plan foresees two postdoctoral researchers (year 2&3 and year 4&5) and two doctoral students (year 1-3 and year 3-5) in addition to the group leader. It is envisioned to give master students the possibility to contribute in different sub-work packages such as XXZZZ. Additionally, some funds are requested to employ student assistants for a total of 3 years distributed over the project duration as required and interested students availability. The other costs consist of smaller detectors and consumables for experiments as well as travel costs for the participation in relevant conferences and workshops which will enable the communication and discussion of results as well as help with establishing new connections and give access to the latest developments. No larger investments are needed, considering the existing accelerators and infrastructure at KIT IBPT.

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Group leader position*	100200	103206	106302	109491	112775	531975
2 Postdoctoral researchers (100%, à 2 years)*	-	88683	91343	94083	96906	371016
2 Doctoral students (75%, à 3 years)*	59850	61645	126989	65399	67361	381246
Student assistants (in total 3 years)	4368	4368	4368	8736	4368	26208
Material costs	29200	9000	7500	6500	3000	55200
Travel	4000	9500	12000	8000	12000	45500
Total	197618	276402	348503	292210	296411	1411146

*The personnel costs follow the DFG Personnel Rates. An annual rise of 3% has been included.