Measurement of the behavior of residual gas particles on cryogenic surfaces to improve the simulation of dynamic vacuum effects

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Introduction

The dynamic vacuum refers to pressure rises occurring during beam operation in particle accelerators. It is caused by charge exchange of beam ions and the stimulated desorption of gas particles from the walls and has to be compensated by the pumps as fast as possible.

The StrahlSim code, which is developed in the synchrotron department at GSI [1], can simulate the evolution of the residual gas pressure, its composition, and its interactions with the ion beam during a realistic synchrotron cycle. The code calculates for each timestep the amount and position of beamlosses and the resulting desorption. Locally elevated pressure values lead to higher beamlosses by charge exchange in corresponding areas during the next timestep, worsening the pressure even more. This self-amplifying effect is a limiting factor for the maximum beam intensity in circular accelerators.

To lift this intensity limit, the cryogenic vacuum chambers of the SIS100 will act as surface pumps. They are able to pump gases according to their vapor pressure curves which is sufficiently low for most gases. This is called *cryocondensation*. An important exception is hydrogen. Its saturated vapor pressure at 4.2 K (temperature of liquid helium) is 6E-7 mbar, which is too high for a stable operation with high intensity ion beams.

Fortunately hydrogen can be pumped to lower pressures by so called *cryosorption* if the surface coverage of the cold walls is sufficiently low [2]. This effect can be characterized by two parameters: The *sticking coefficient* describes the probability of a gas particle impacting on the surface to be bound. It is directly linked to the pumping speed provided by the cryogenic walls. The *mean sojourn time* describes how long a particle remains bound to a surface. Both parameters together determine the equilibrium pressure.

Measurement of the parameters

The planning and setup of an UHV experiment (Figure 1) to determine these parameters have begun. The cold surface that will be tested is provided in the form of a small chamber which is cooled by a cold head. The target temperature range is 5 to 20 K. The measurement will be divided in two phases: Firstly the pumping speed of the chamber is quantified at different temperatures and surface coverages to get the sticking coefficient. In the second phase, the corresponding equilibrium pressure is evaluated which yields the sojourn time.

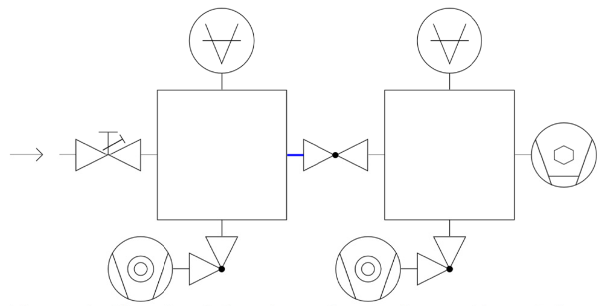

Figure 1: Sketch of the planned experiment. From left to right: Gas inlet, first recipient with extractor gauge and turbo pump, defined conductance (blue), valve to be closed for phase two, second recipient with cold-warm-transition to the cold chamber.

To link the pressure values measured by the gauges to the desired parameters, the simulation code Molflow+ [3] is used. It tracks gas particles through a system from a gas source to surfaces with non zero sticking by usage of a Monte Carlo based algorithm (Figure 2).

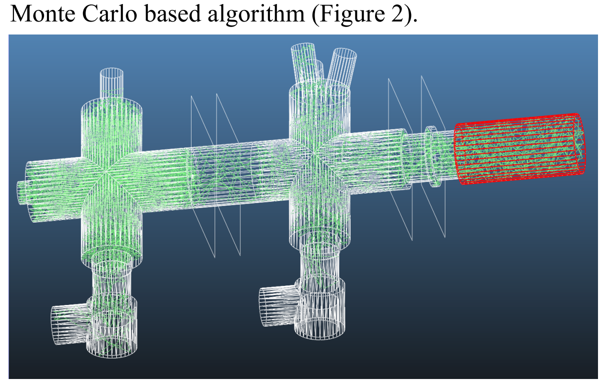

Figure 2: The Molflow+ model that is used to determine the properties of the experimental stand. The cold chamber (red) has a sticking assigned. This leads to a measurable pressure difference between the recipients.

The results will finally be integrated into StrahlSim to improve the quality of simulation for superconducting synchrotrons with cold surfaces.

References

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