Design of SNAKE for the Micro Irradiation of Cells

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The ion microprobe SNAKE (**S**uperconducting **N**anoscope for **A**pplied Nuclear (**K**ernphysikalische) **E**xperiments) at the Munich tandem accelerator has gone into operation during 1999. At low ion currents, typically used for biological microirradiation experiments, the facility is capable of focusing 10 - 30 MeV protons or heavy ions with energies up to 200 MeV to a submicron beam spot size. Using 90 MeV ^{32}S ions a spot size of 700 nm has been demonstrated [1]. Therefore, SNAKE represents a promising basis for the selective irradiation of specific parts in living cells like cell nucleus, cytoplasm or membrane with single, counted ions. Beyond it, the wide range of stopping powers over three orders of magnitude and the large range in biological material, provided by the high energy ions at the tandem accelerator, offer experimental perspectives exceeding other already existing microirradiation facilities. Among many possible experiments three examples for answering radiobiological questions should be exposed:

1. Clarification of the role and spatial-temporal dynamic of repair proteins, which are able to reconstruct a broken DNA-molecule.
2. Biochemical interaction between irradiated and non-irradiated cells located in a neighbourhood, the so-called "bystander-effect".
3. Probability of cancer initiation by low dose irradiation, where biological cells receive no more than one ionizing particle.

The instrumental problem of microirradiation of biological cells with counted ions can be divided up in separated components, namely a focused ion beam, a fast beam switch, an ion detector system, a beam exit window, a cell container and a microscopy system (fig.1).

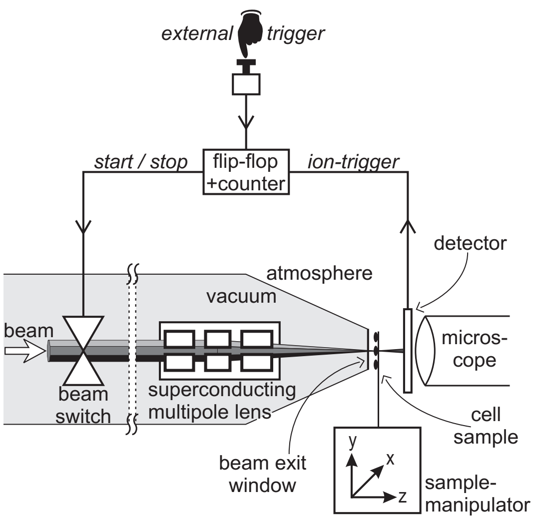

Fig. 1: Schematical setup for the microirradiation of living cells with single, counted ions.

For the preparation of single ions, the "Posselt-Chopper" of the tandem accelerator, which is located behind the analysing magnet, is used as fast beam switch. This is done in driving the electrostatic steerer system by a high voltage MOSFET switch ($V_{max} = 8\,\mathrm{kV}$). An external manual trigger allows the beam to pass the chopper, while the first ion irradiating the cell sample stops the beam again. The stop signal is generated by a suitable detector system placed in front of or behind the sample. The precondition for this special beam preparation is a drastical beam current reduction to a count rate of no more than about 1kHz at the target, which is performed by the SNAKE object and divergence microslits [2]. A first test of this setup was carried out in November 2000. Using a 70 MeV ^{12}C ion beam and a silicon detector for stop signal, it enabled to get single ions at the target on demand.

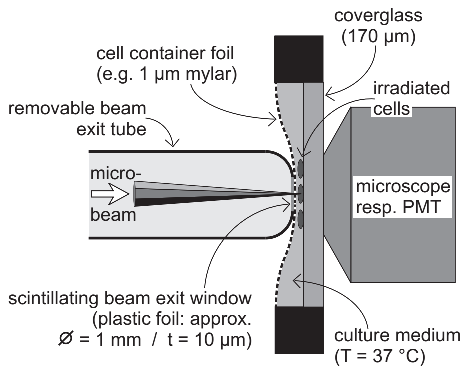

Fig. 2: Cell container in irradiation position.

To permit experiments with living cells, these must be handled completely under atmospheric pressure in a suitable cell container, which can be positioned with μm-resolution by an existing four-axis manipulator. Therefore, a beam exit window, separating the beam tube vacuum from surrounding atmosphere, is needed. The planned arrangement is shown in fig.2. For practical reasons, given at the microbeam setup SNAKE, the exit window will sit on top of a narrow, removable beam tube within the aerated target chamber. In building the exit window from a plastic scintillator foil with a thickness in the range of about 10 μm, it shall serve as stop detector for single ion preparation, too. The passage of an ion produces a light flash in the window, which can be detected using a photomultiplier tube. If the irradiation location has a distance of less than 0.1 mm from such a window, the broadening of the microbeam spot due to angular straggling can be neglected. An optical microscopy system, especially suitable for biological examinations, is currently under discussion.

References

[1] G. Dollinger *et al.*, Jahresbericht 1999, p. 89
[2] O. Schmelmer *et al.*, Jahresbericht 1998, p. 101