MAFF — Munich Accelerator for Fission Fragments

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The **M**unich **A**ccelerator for **F**ission **F**ragments (MAFF) is a reactor-based Radioactive Ion Beam (RIB) facility which is being planned and set-up at the FRM-II mainly by the group for experimental nuclear physics (Prof. Habs, LMU) and the physics department E12 (Prof. Krücken, TUM).

The goal of this installation is the production of very intense beams of neutron-rich isotopes that will be available for a broad range of nuclear physics experiments as well as applied physics and nuclear medicine [1,2,3]. In a first step the beam will have an energy of 30 keV (low-energy beam). In a second step also a high-energy beamline will be set up where the ions are post-accelerated to energies adjustable in the range 3.7–5.9 MeV/u.

0.1 Authorisation procedure

A first tender has been filed by the TÜV Süd for the MAFF authorisation procedure that required further negotiations which are finally coming to an end now. A crucial issue concerning the cost of this procedure and of the MAFF system is the distribution of radioactivity within the system which has therefore been evaluated by two different methods:

0.2 Distribution of radioactivity in the MAFF system

0.2.1 Time-independent method

The target/ion source unit of MAFF releases the great majority (98 %) of radioactive nuclides in a non-ionised state. About 30 % are emitted in gaseous form (mostly noble gases) the rest non-gaseous. The gas particles undergoing multiple reflections from the beamline walls, have an opportunity to spread along the MAFF beamline much further than the others which will usually stick to the beamline surface at a point where they make first contact after having been emitted. The distribution of the non-ionised radioactivity along the beamline is important from both experimental and radiation safety points of view. In order to get a good estimate, Monte Carlo computer simulations were performed with the help of the commercial code MOVAK3D [4]. The calculated fraction of non-ionised gaseous radioactivity close to the experimental area is at the level of $\sim 10^{-7}$ of the activity produced in the target. The non-gaseous activity remains within the reactor beamtube.

0.2.2 Time-dependent radioactivity distribution

Also for the time-dependent calculation a Monte-Carlo approach is used to predict the surface coating of the beam line for all radionuclides. Here the surface areas are used as measure for the probability that they are hit by a particle. The program is completely time-dependent to implement radioactive decay. As a result the surface coating for all radionuclides within the beamline is obtained.

For a test geometry without time-evolution both codes produced the same results within a factor of two.

Ions are transported electrostatically towards the mass-separator, with a complex slit system in the focal plane. All unwanted ions are stopped at the slits, resulting in a high level of radioactive contamination. Material corrosion caused by sputtering will release previously implanted radionuclides. To reduce this effect, the slit geometry can be modified. So far a flat structure has been compared to a wedge shaped structure, both of them enclosed in a box with a small opening to reduce the solid angle. The wedge structure leads to a 14 % reduction in sputter yield resulting in a total sputter yield of 0.1 for beam particles.

0.3 The vacuum system of MAFF

The vacuum system encloses the extremely radioactive target/ion source with a fission product activity of several 10^{14} Bq after one reactor cycle of 52 days. Approximately 20 % of the load of 1 g highly enriched ^{235}U are burnt in one cycle. If all emitted fission products were solid material, about 35 g would be deposited on all walls of the vacuum system during the design lifetime of 30 years. This will not pose a storage problem to the high-vacuum system, and since the vapour pressure of solid material is too low to transport the solid fission products into the vacuum pumps, they will remain at the walls of first deposition if the vacuum is better than 10^{-3} Pa. Even volatile elements like iodine or bromine would be trapped in the condensed film due to chemo-sorption because a fission product is always a single ion or an atom.

18 refrigerator cryopumps will be installed as high-vacuum pumps, only 9 of them required, the second set is for redundancy. They are a slightly modified model COOLVAC 800 (CF) from Leybold. As all-metal gate valves and metal seals will be used, the radiation hardness of 10^7 Gy is not spoiled by destruction of elastomeric sealings and no leakage due to age-hardening of the gaskets may occur.

About 30 % of the created fission products are noble gases. If they were stable and would not decay to low-vapour pressure elements after short half-lives, about 4500 Pa·l gas must be pumped mainly by the two cryopanels. A smaller amount and the rest of the released gas from the cryopanels during their regeneration is pumped by the refrigerator cryopumps. The part of gases which did not decay is then transported into decay tanks during warm-up and regeneration of the cryopumps.

15 dry roughing pumps (some for redundancy) are applied for roughing and regeneration purposes. The ACP 28 from adixen (Alcatel subsidiary) has been chosen due to its small leak rate of $5 \cdot 10^{-5}$ Pa·l·s^{-1} and the capability to work below atmospheric pressure. This is a must to prevent radioactivity from escaping into the experimental hall in case of leaks.

The radioactive gases from the decay tanks can be released into the FRM-II exhaust gas system, but even small amounts of aerosols must be avoided. Therefore the gases from the decay tank will be transferred into a second tank via a slow diffusion filter which is under development. Aerosols should not pass this type of filter.

It would be very expensive to design all components of the vacuum system for over-pressure situations which might occur if one of the cryopanels or a cold finger from a cryopump leaks. Therefore the volume of the beam tube unit will be enlarged by adding a 1000 l ballast tank.

0.4 Development of components

0.4.1 The in-pile ion source

A prototype of the in-pile ion source of MAFF is currently developed and constructed (see fig. 1). An ion source for surface ionisation mode is designed and being built. The surface ionisation source provides ionisation efficiencies of nearly 100 % for alkaline metals. This prototype will consist of reactor suitable materials. The MAFF target/ion source has to withstand a maximum thermal neutron flux of $1.5 \cdot 10^{14}$ n/(cm^2 s) and is located at $\sim$ 50 cm distance to the reactor core inside the through-going zircaloy beam tube. The ion extraction system has been redesigned with the computer code IGUN using one electrode formed by the heat shield. The first prototype of the target/ion source [5] has used a two-electrode extraction system. That prototype has shown that a new construction is required in order to protect the ceramic insulators from metal and carbon vapour from the target and the heat shields.

Much effort was spent on the development of appropriate UC_x targets. The target will be externally heated with a tungsten filament by electron bombardment and thus kept at a temperature of about 2400° C, which provides rapid effusion of the fission products into the target channel. The target is veiled with a cylinder of vitreous carbon and a protecting rhenium container at which outlet the surface ionisation takes place. Re has been chosen because it is most inert against C and U at high temperatures, has a high melting point (3180° C) and can best withstand the high neutron flux.

Several heat shields are supposed to confine the high temperature in the center of the source. Although Re has the disadvantage of a rather high neutron capture cross section it will be used for the two innermost heat shields due to its thermal strength and short half-life of activation. The other heat shields and the screws will consist of Mo while the ceramic insulators will be made of BeO, which can withstand higher temperatures than Al_2O_3. All parts of the ion source have been ordered and the assembly and operation of the source on the test bench is foreseen in 2005.

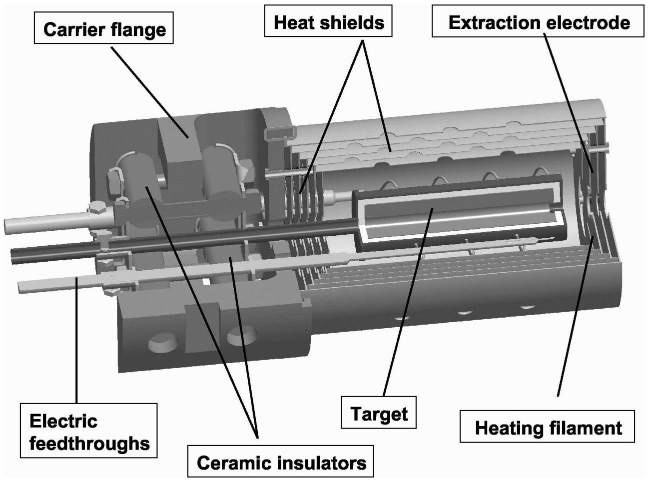

Fig. 1: Construction of the MAFF target/ion source.

0.4.2 Lens trolley prototype development

The design of the lens trolley and the support structure has progressed and construction of the prototype has started. It will consist of the source trolley's main body, the adjustment mechanics, drives and the support frame. During design and construction common TÜV requirements were kept in mind so that some parts of the prototype might be used also for MAFF.

The aim of the prototype is testing of certain crucial issues like the adjustment and movement of the trolley and the functionality of the drives.

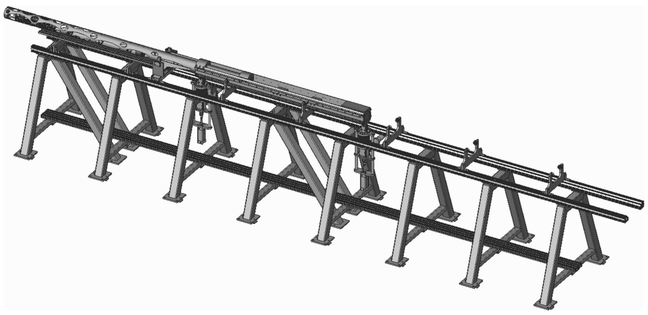

Fig. 2: The lens trolley test setup

0.4.3 Commissioning of the cryopanel prototype

Close to the fission source on either side of the MAFF beamtube, a cryopanel will prevent the migration and spreading of unwanted volatile radioactivity in the beamline system by localising gaseous radioactivity on surfaces cooled down to about 12 K. Being the central element of the radioprotection and safety system for MAFF, an extensive test programme is needed to verify the design specifications and to characterise the performance of the cryopanel. Therefore a prototype has been built, consisting of a double-walled tube where cold Helium gas (inlet temperature 12 K) will flow through. It has been mounted in the MAFF test beamline at the MLL which reflects the exact geometrical properties of the innermost part of the MAFF beamtube at the FRM-II.

The cryopanel was connected to a helium refrigerator with a cooling power of 150 W at 4 K, which for the cryopanel tests will be operated at a temperature of 12 K. Therefore a 10 m long vacuum-isolated transfer line for in- and outlet of the cold gas was installed between the refrigerator and the test beamline.

In a first commissioning test the cryopanel was cooled down to 12 K. Successful operation could be demonstrated by the improvement of the vacuum pressure from initially $4 \cdot 10^{-7}$ mbar to $2 \cdot 10^{-8}$ mbar in cold state.

The next step will be the installation of temperature sensors to study the thermal profile along the cryopanel as well as measurements of the pumping capacity and retention capabilities for gaseous elements.

0.4.4 MLL-Trap

A Penning trap system similar to REXTRAP at ISOLDE (CERN) or JYFLTRAP at Jyväskylä is being set up at the MLL to measure nuclear masses with high precision and/or to do nuclear spectroscopy at trapped ions. The superconducting magnet has been delivered and shimmed to an inhomogeneity of $\Delta B/B \leq 0.3$ ppm. The trap system will first be used at the MLL and can later be moved to MAFF.

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