The feasibility study for the medical radioisotope: astatine-211 production by the gas cell-based laser ionization technique

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Astatine-211 is one of remarkable advantage isotopes for targeted α-particle therapy. RIKEN Nishina Center has been providing many types of medical radioisotopes, particularly a large amount of ^{211}At.[1] Astatine-211 can be produced from natural bismuth target via the ^{209}Bi$(\alpha, 2n)^{211}$At nuclear reaction. The adjustment of α-particle energy is constrained from maximizing ^{211}At production to avoid production of ^{210}At, which yields the undesirable α-particle emitting daughter, ^{210}Po. The chemical separation of ^{211}At and ^{210}At is, in principle, incompatible in the recovery process of ^{211}At from the target.

Here, we propose a new idea to use the physical separation of ^{211}At and ^{210}At by the gas cell-based laser ionization technique. This technique utilizes an isotope separation by the element and mass selective low-energy beam transportation. Figure 1 shows the conceptual diagram for this technique. The bismuth target irradiated by the cyclotron beam is installed into the gas cell. Atomic/ionic At or any other isotopes are evaporated from the target by resistive heat transfer and then they are transported to the exit area by an inert gas flow. Three-color pulsed laser beams are sent to the gas cell exit area for laser ionization of At.[2] The laser wavelength enables element selective ionization by using a resonant excitation scheme in the atomic structure. The excitation energy for the removal of single electron is acquired stepwise by laser photons. Photo-ionized astatine isotopes are sent to the quadrupole mass separator for the separation of ^{211}At and ^{210}At via multipole ion beam guide in the differential pumping stage. Consequently, a highly pure ^{211}At ion beam is collected. The radioactive contamination can be minimized by using the closed gas circulation[3] and by installing the entire system in a draft chamber.

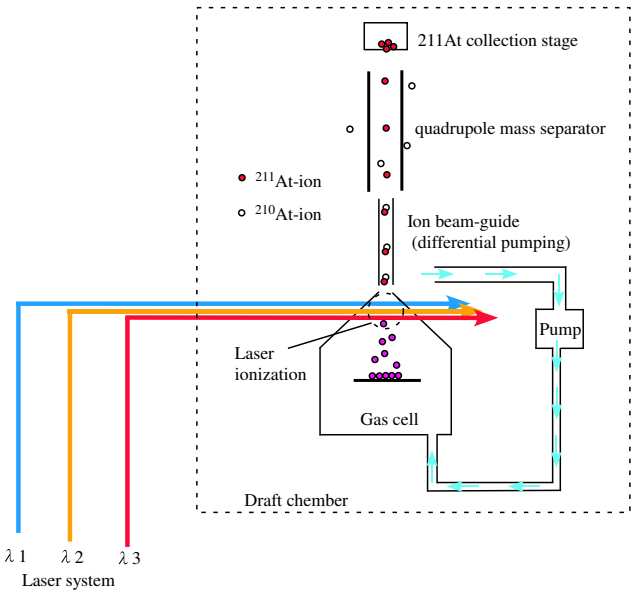

Fig. 1. Conceptual diagram for ^{211}At production. The whole system is as small as to be placed in the general draft chamber.

In 2023, we will start the feasibility study for this technique as the following steps:

- Laser ionization test for astatine isotope in vacuum to investigate efficient ionization scheme.
- Extraction and collection test for ^{211}At.
- Evaluation of the radioactive purity and collection efficiency.

The potential advantage of this technique is expected in the following parts: (1) Facilitate use of the best α-particle energy for the cyclotron for the maximum production of ^{211}At, without worrying about any other isotope production, such as ^{210}At. This will result in 3-5 gain in the production efficiency. (2) Minimization in human exposure/contamination against alpha emitting radioactivity and radiation. For the first test, we will install the highly activated target into the gas cell manually. In future, the bismuth target including gas cell will be set on the beam axis of the cyclotron beam line, then the gas cell unit can be treated instead of dealing the target by human hands. This is crucial if the cyclotron beam intensity is very high.

The feasibility study for new production technique of ^{211}At has been started. The fabrication and development of the whole system is in progress. If the feasibility is confirmed, this technique will be extended to other medical radioisotope productions such as ^{213}Bi, ^{111}In, and ^{225}Ac.

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References

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