LASER EVAPORATED ALUMINIUM IN ECR2 ION SOURCE [1]

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A 50watts CO_2 laser was employed to heat the laser-oven, its temperature higher than 1200℃, and that could produce Al^{6+} ions more than 50μA.

1 Introduction

A 10GHz ECR2 ion source had been constructed as an external source of HIRFL injector SFC to provide many species ion beams of gaseous elements since 1995. Recently many nuclear physics studies and atomic physics experiments require HIRFL to accelerate highly stripped ions of metal elements. It is well-known that a number of various methods have been used as a means of introducing solid into ECR plasma. These methods include the use of externally heated ovens, plasma heated crucibles or 'boats', direct plasma evaporation of metallic wires and oxides of the metal elements. ECR2 is very compact source and hasn't access or gaps for an externally heated oven between the segments of the sextupole. In general, solid material rods or crucibles are directly inserted into ECR plasma which can evaporate rapidly both for low- and high-temperature solids. Nevertheless with this methods, the plasma is used both for evaporating and ionizing the sample, so some hot electrons are lost in heating process. In order to separate these two functions, a special inner oven has been developed in GANIL[1] and Grenoble[2], which also serves as coaxial guide for the microwave. The technique difficulty lies in its size, in its introduction inside the source, and in the electric energy transfer due to the compactness of the source. Therefor, we are attempting to overcome these difficulties to use a c.w laser heating an inner oven, easily to attain the temperature higher than 1200℃, and produce Al^{6+} ions of more than 50μA.

2 ECR2 ion source[3]

ECR2, as show in Fig.1, is a 10GHz source. Two groups of solenoids with 3 pancakes for each produce the necessary magnetic mirror field. The magnetic fields at two mirror throats and extraction hole are 10.4KG, 7.3KG, and 6.5KG respectively. The B_{min} inside the cavity is about 3 KG. A hexapole of 162mm in length consists of pieces of permanent with NdFeB material. The structure of the hexapole is similar to that of standard CAPRICE. The radial fields on the cavity wall of middle and terminals of the hexapole are 8KH and 7KG respectively. Superposition of mirror and hexapole fields forms a ECR zone ranging 5.5cm in axial direction and about 3cm in radial direction.

3 Laser heating oven

Due to the inner tube diameter of coaxial microwave guide in ECR2 is only ϕ6mm~ϕ8mm, if the diameter were enlarged that would influence on microwave transporting in coaxial guide, that apparently limits the inner oven size. Therefor, we are trying to overcome these difficulties to employ a c.w laser heating technology. Because the the laser heating energy is from laser beam, and it is almost not influenced by the ECR plasma while the laser beam transporting its energy in ECR ion source. Furthermore the laser impact area on the inner oven is also defined by the laser beam, in general, its diameter only is several millimetres. So, the laser heating oven not only can be made very small, its position but also can be put more flexibly in ECR ion source.

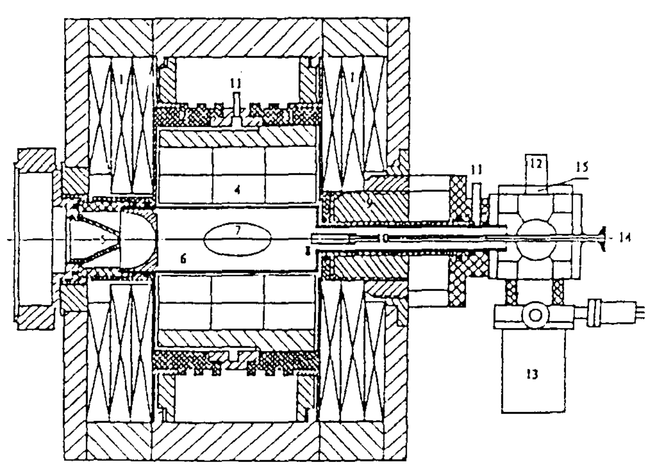

Fig.1 HIRFL 10GHz ECR2 ion source.

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The laser-oven was made of tantalum. Comparing to GANIL's "micro-oven" and Grenoble's special oven, it was smaller in dimension, 7.5mm in diameter and length only about 20mm, which can be put into quartz tube as coaxial guide, as show in Fig.2. The laser beam can heat the inner oven from back, which is injected into ECR source along the inner tube of coaxial microwave guide, and it can The laser is a commercial medical and continuous ultrared CO_2 laser(λ=10.6μm). Its output power is increased from 4watts to 57watts with increasing discharge current up to 18mA, as show in Fig.2. Only when the working current is larger than 8mA, the CO_2 gaseous discharge become enough and stable throughout the laser tube, that will cause the output power to produce a jump at the threshold. The variation of the temperature of the laser-oven with working current that corresponding to laser heating power also was displayed in Fig.3, of course, there was a temperature jump too when the output power jumped. The temperature of laser-oven could be controlled from 85 to 1200℃ at standard pressure by regulating the laser working current from 2mA to 18mA. If the laser-oven was installed in ECR source, because of high vacuum decreasing heat conduction, it must have exceeded the limitation.

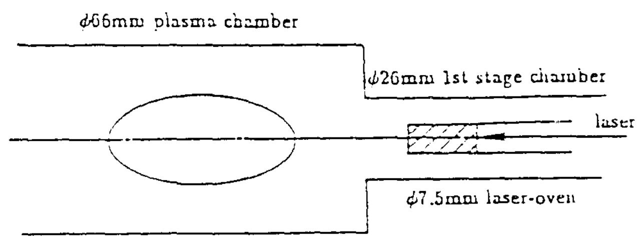

Fig.2 Schematic diagram of the laser oven in ECR2 ion source

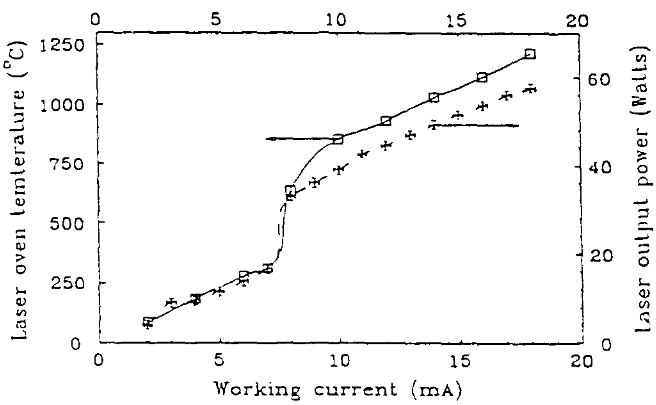

Fig.3 Dependence of laser output power and laser oven temperature on the working current.

4 Laser Evaporated Aluminium in ECR2

This method of laser evaporating was attempted to produce aluminium ions in ECR2 ion source, for the saturation vapour pressure of aluminium is about 10^{-2}mbar at 1200℃, that's enough for getting aluminium ions in ECR ion sources. Firstly, the laser heating oven was put before the first stage of ECR ion source, the evaporated aluminium vapour could directly be ionized by the first stage. In this case, ECR ion source could be being operated with two stages, that's advantaged of elevating the current of metal ions. But it was found in the test, that a metal coating rapidly formed on the quartz tube with the metal vapour ɔraying out from the oven and stopped the microwave ·ansporting to the first stage, thus the first stage of ECR ɔn source didn't work. Then, the laser heating oven was ut on the head of quartz tube and connected with inner ıbe of coaxial by the thin copper tube, that made the nicrowave could smoothly go into the second stage along he coaxial tube and thin copper tube and oven. For the netal vapour evaporated by the laser heating oven quickly :ould diffuse to the plasma cavity wall and not be ionized ɔy the ECR plasma, the laser heating oven was gradually push to the second stage of ECR ion source untill the metal vapour could directly inject into ECR plasma and be ionized to become metal ions. Al^{6+} ions of more than 50μA were obtained by this way in ECR2 ion source, as showed in Fig.4, with oxygen as supporting gas.

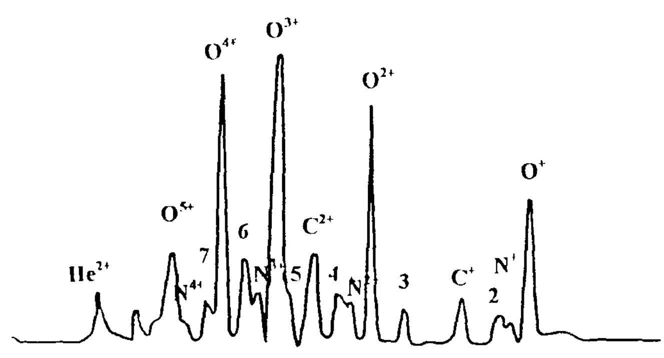

Fig.4 Charge state distribution of Al ions.

5 Conclusions

Because of the laser reflection from metal surface, that bates the actual heating power, one has to choose higher power c.w laser in order to attained higher heating temperature. The highest power of a commercial c.w CO_2 laser may reach to around 150 watts, if the laser absorbance of solid material generally was about 80~90%, then there would have more than 120 watts power used to heat inner oven. As the area of laser heating is smaller and higher heating efficiency, the laser heating will obtain higher heating temperature than electric heating. Moreover, the structure of oven is simpler and the position of oven is moveable and flexible.

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References

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