Search for suitable scintillation materials for the pepper-pot type emittance meter for diagnostics of low-energy heavy ion beams from an ECR ion source†

T. Nagatomo,[*1] V. Tzoganis,[*1,*2,*3] M. Kase,[*1] T. Nakagawa[*1] and O. Kamigaito[*1]

For diagnostics of the low-energy and high-intensity heavy ion beams extracted from an ECR ion source (ECRIS), we are developing an emittance meter (EM) based on the pepper-pot method[1)]. Inside the ECRIS, to generate a multiply charged ion beam, ions and high-temperature electrons are confined together as plasma in a strong mirror magnetic field. The mirror field is the superposition of a radial hexapolor and axial solenoidal fields. Therefore, a heavy ion beam extracted from the ECRIS has no longer a round nor a gaussian shape, and has a triangular spacial distribution. Hence, it is important to measure the transverse phase space distribution (x, p_x, y, p_y) simultaneously to improve transport efficiency through the accelerator complex. The pepper-pot EM is perfectly suited to obtain the 4D distribution. Furthermore, because of the high processing power of PC, analyzing time by the pepper-pot EM is estimated as a few seconds. It is remarkably faster than the estimation time of ~ 10 min by a slit-scanning EM that is currently employed at RIKEN.

The simplest way to obtain a beam-spot image is to utilize a scintillation plate; for example, a plate with its surface covered with a scintillator, KBr, is commonly used as a beam viewer. However, there is no utilizable quantitative scintillation data, such as degradation of light emission for high- intensity and low-energy ion beam from the ECRIS. If a scintillator has comparably rapid light degradation that depends on the ion beam intensity, the obtained transverse 4D distribution in turn results in distortion. Therefore, as the first step, we have evaluated the applicability of several scintillators whether they are applicable to the imaging screen for this purpose.

Scintillation crystal plates made of quartz, Eu-doped CaF_2, Th-doped CsI, and KBr were tested. The 18-GHz superconducting-ECRIS was used to produce the proton-, $^{12}C^{4+}$-, $^{16}O^{4+}$- and $^{40}Ar^{11+}$-beams. The extraction voltages were 6.5 kV and 10.0 kV for the proton beam and the others, respectively. Each sample was placed behind the pepper-pot mask which has a 49×49 array of pinholes with diameters of 0.1 mm and a pitch of 2 mm. Figure 1 shows typical images of the beam spots with the proton beam, for which the current was typically 50 μA. In the case of the proton beam, the fluorescence intensities of all the scintillation materials tested, except for quartz, degraded exponentially with increasing irradiation time as shown in Fig. 2. The time constant was a few minutes with continuous proton-beam irradiation. A quartz surface impinged by the proton beam exhibited no degradation of fluorescence intensity as seen in other samples, however, with heavy-ion beams, even the quartz showed similar degradation of the fluorescent intensity as the others. Heavier ions are considered to prefer knocking out atoms on the material lattice to ionization, which induces the light emission. As a result, it is difficult to use common scintillation materials for the imaging plate, which is directly exposed to continuous heavy ion-beam impacts. Thus, the heavy ion beams must be converted into light particles, for example, a micro channel plate can convert ions into electrons.

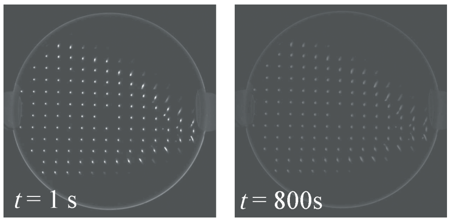

Fig. 1. Obtained images of the proton-beam spots with a CaF_2(Eu) crystal. The photos on the left and right were taken at the irradiation time of 1 s and 800 s, respectively.

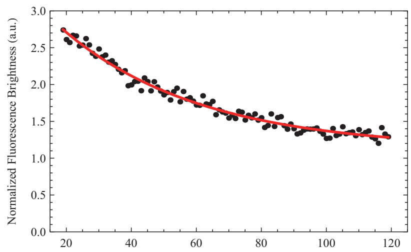

Fig. 2. Obtained degradation of fluorescence intensity induced by proton beam impinging on a KBr crystal.

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*1 RIKEN Nishina Center
*2 Cockcroft Institute, Daresbury, Warrington WA4 4AD, United Kingdom
*3 Department of Physics, University of Liverpool, Liverpool, Merseyside L69 3BX, United Kingdom

Reference

1) H.R. Kremers et al., Rev. Sci. Instrum. **84**, 025117 (2013).