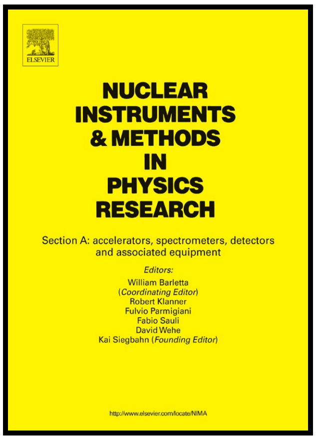

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PII: S0168-9002(17)30442-4
DOI: http://dx.doi.org/10.1016/j.nima.2017.04.012
Reference: NIMA59800

To appear in: *Nuclear Inst. and Methods in Physics Research, A*

Received date: 25 January 2017
Revised date: 13 March 2017
Accepted date: 5 April 2017

Cite this article as: Akihiro Iino, Seiya Yamaguchi, Takakazu Shintomi, Toshiyasu Higo, Yoshisato Funahashi, Shuji Matsumoto, Shinichiro Michizono Kenji Ueno and Katsumi Endo, Development of low-loss cryo-acceleratin structure with high-purity copper, *Nuclear Inst. and Methods in Physic Research, A,* http://dx.doi.org/10.1016/j.nima.2017.04.012

Development of low-loss cryo-accelerating structure with high-purity copper

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Abstract

In this paper, the development of an accelerating structure with high-purity copper operated at approximately 20 K is described. The aim is to obtain a dramatic increase in the quality factor (*Q* factor), which is an important parameter as regards enhancement of the acceleration gradient in a normal-conducting accelerating structure that has been operated at room temperature in the past. First, the *Q* factors of pill-box cavities comprised of two types of copper with different purities (99.99% and 99.99998%) were measured, at room temperature (300 K) and at a relatively low temperature (20 K); the resultant ratios, Q_0(20 K)/Q_0(300 K), were then compared with calculated values. Hence, it was found that the experimental and calculated values agree to within several percent, and converge to a constant value (approximately 5.3) when the residual resistance ratio is above 500. Next, a C-band accelerating structure was fabricated using a copper material having a purity of 99.99998%, and high-power testing of the structure was conducted at 20 K. Hence, it was found that the accelerating gradient E_{acc} reaches 30.9 MV/m with a 1.0-μs pulse width and 50-Hz repetition rate. In the high-power test, it was revealed that the radiation dose rate for C-band structure (20 K) was about two orders of magnitude lower than that for S-band structure (303 K) under the same conditions. Further, the magnitude of the dark current generated in this structure was estimated to be several femtoamps, which was below the detection limit. This finding was based on the assumption that the dark current magnitude is proportional to the radiation dose; however, no dark current was observed.

Keywords: Accelerating structure; Low temperature; Copper; High-purity; *Q* factor; High-power test.

1. Introduction

An increasing number of low-energy electron linear accelerator (linac) applications have been reported in recent years, in both the industrial and medical fields. The majority of these linacs require downsizing and low radiation doses for operation under low-energy conditions. For example, a coherent parametric x-ray radiation (PXR) source based on a normal-conducting cryogenic compact electron accelerator has been considered for medical applications; our research group has developed a device to satisfy these requirements [1]. A schematic of the compact accelerator under development is shown in Figure 1.

The accelerator shown in Figure 1 has three characteristics. First, the radio-frequency (RF) power that is not used for beam acceleration is recovered and the input power of the accelerating structure is amplified; thus, an increased acceleration gradient is obtained. Second, the RF power that is not used for beam acceleration reduces the beam energy in the decelerating structure, and the generated radiation dose is reduced at the beam dump. Third, by operating the accelerating and decelerating structures at approximately 20 K, reduced RF power loss and an increased energy gain within the system is obtained. Figure 2 shows the energy gain in the system [1].

Although the high-frequency characteristics of normal-conducting cavities at low temperatures have been reported [2], it is very interesting to operate these structures at low temperature in order to obtain a high gradient and to reduce the radiation dose in the compact accelerator. Previously, we performed high-power testing of the accelerating structure described above at a low temperature of 20 K [3]. In the present paper, the characteristics of a C-band accelerating structure comprised of high-purity copper, and operated at 20 K are described.

The remainder of this paper is organized as follows. Section 2 discusses the shifts in the quality factor (*Q* factor) and resonant frequency in response to changes in the temperature of the test cavity, which is com-