A.13: Protection of intellectual property rights on laser welding technology for superconducting radio frequency cavities

Raja Ramanna Centre for Advanced Technology (RRCAT) has taken up a program on development of superconducting radio frequency (SCRF) technology aimed at setting up a high intensity superconducting proton linac, which is a major project being planned at RRCAT.

With this objective, assimilation of SCRF technology has been taken up at RRCAT. Technology assimilation is based on a mixed approach, which consists of adopting best practices prevalent elsewhere, together with developing innovations which would provide better functionality and lower cost. An example is the development of SCRF cavity fabrication technique using laser welding process.

Intellectual property right (IPR) protection is considered today as a vital element of technology development process. Therefore patent applications were filed through Patent Cooperation Treaty (PCT) route. Recently, Japanese patent (JP 5632924) has been granted with title "Niobium based Superconducting Radio Frequency (SCRF) Cavities comprising Niobium Components joined by Laser Welding; Method and Apparatus for manufacturing such cavities". Patent applications are also in advanced stages at European, Indian, and US patent offices. Well known industrial giant Mitsubishi Heavy Industries (MHI) has cited this patent in their US patent application no. (US 2012/0256563 A1), which was filed after RRCAT's patent.

The very first 1.3 GHz Tesla-shape SCRF cavity fabricated at RRCAT using laser welding process reached an accelerating gradient (E_{acc}) of 31.6 MV/m with a quality factor (Q_0) of 1.0×10^{10} at 2K. It is a standard result for any well made SCRF cavity.

This technique uses an Nd:YAG laser for welding of components of SCRF cavity made of niobium. The welding is carried out in a specially designed welding rig in inert gas environment. Conventional fabrication technique for SCRF cavities prevalent all over the world is based on electron beam welding (EBW) of niobium components in high vacuum. This innovative fabrication technique based on laser beam welding developed at RRCAT has a very promising future due to several inherent advantages such as significantly reduced capital cost (25times) and operating cost (few times), small heat affected zone, flexibility in approach to weld location by means of fiber optic beam delivery, no necessity to weld in vacuum and an enhanced rate of production.

Laser beam welding (LBW) is a well-known technology finding application in many areas of industry. But the innovation here lies in using flexibility provided by laser welding to reduce heating of cavity thereby facilitating the use of inert gas environment instead of high vacuum.This facilitates an easier fabrication process at lower cost without compromising on performance.

The major infrastructure for LBW based SCRF cavity fabrication includes specially developed Nd:YAG laser, a welding rig, and a target maneuvering system. Tailor-made, indigenously developed Nd:YAG laser provides an average output power of 500 W with a peak power of 10 kW. Laser output pulse shape can be varied in time domain with pre-determined heating and cooling rates. Nd:YAG laser systems with such specifications are hardly available commercially. Laser beam is delivered to weld joints by means of an optical fiber and lens arrangement passing via an optical feed through into the welding rig.

Specially developed SCRF cavity welding rig contains a stainless steel chamber with motion feed through, optical fiber feed through, and gas feed through to carry out welding in an inert gas atmosphere. Laser welding process and parameters were initially optimized on niobium samples to achieve good surface smoothness with minimum HAZ, distortion, shrinkage, and minimum degradation in residual resistivity ratio (RRR). Using optimized process parameters, a single cell 1.3 GHz SCRF cavity was fabricated. Fig. A.13.1 shows a view of first laser welded 1.3 GHz SCRF cavity.

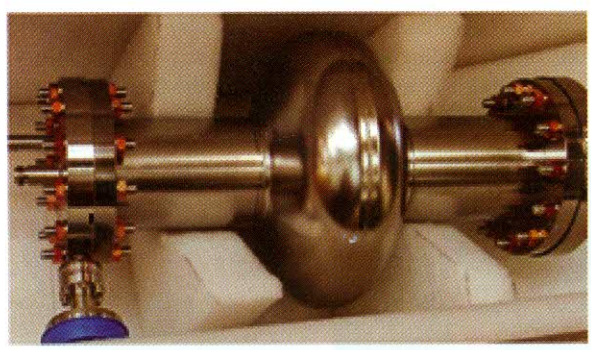

Fig. A.13.1: First laser welded SCRF cavity (RRCAT)

The advantages associated with LBW technique for fabrication of SCRF cavities makes it an attractive choice for future accelerator projects. To the best of our knowledge, these are the first high quality test results, of an SCRF cavity, completely made with laser beam welding process in the world.

As the novelty and advantages of this technique has been accepted worldwide, further efforts are underway to improve performance of single cell cavities and also to fabricate few multi-cell cavities with repeatable performance using this technique.

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