Title of Seminar

"Development of Cryogenic Refrigeration Technology and Applications to Superconducting Systems" presented by TAEKYUNG KI (KEK in Japan) for 80 min on 18th July, 2016

Abstract

Do you know "how we get cryogenic temperatures" and "why we use cryogenic refrigeration"? In this seminar, the cryogenic refrigeration technologies, especially "cryocooler and liquefier", and the applications to accelerator systems will be presented. At part I, a systematic design method of a pulse tube cryocooler, which uses a gas piston in a pulse tube to reach at cryogenic temperatures, and energy flow (energy conversion) measurement in pulse tube cryocoolers will be introduced. At part II, applications of cryogenic refrigeration to superconducting systems of accelerators will specifically be introduced.

Part I: Design of Pulse Tube Cryocooler and Energy Flow Measurement

To design and fabricate a very efficient Stirling-type pulse tube cryocooler, it is necessary to develop a standard procedure and understand the energy conversion process in a pulse tube cryocooler. The final goal of this research is to develop a 4 K cryocooler and a very efficient cryocooler for applications to conduction-cooled superconducting magnets and spectrometers of spaceships. As a starting point, a systematic design method and a stable instrument for measuring physical properties are developed at KAIST.

1. A systematic design method for developing an efficient Stirling-type pulse tube cryocooler is proposed. Each part provides a step-by-step procedure for developing an efficient Stirling-type pulse tube cryocooler. A prototype pulse tube cryocooler is fabricated as an on-board type for cooling a superconducting motor. The cryocooler has high efficiency and successfully cools down the motor while it is rotating together with 240 rpm.

2. To increase the efficiency of 4 K cryocoolers, it is necessary to know the energy conversion process and the effect of real gas in the cryocoolers. A stable instrument, which can be used in cryogenic environment, is developed for real-time measurement of physical properties and installed at boundaries of two Stirling-type pulse tube cryocoolers. The detailed physical properties of oscillating helium flow are measured while the cryocoolers operate at 90 K. From the measured physical properties, the energy flows are identified so that we can precisely know the energy conversion process in two Stirling-type pulse tube cryocoolers. The proposed method is useful for clarifying energy conversion process and analyzing the tendency of physical conditions in cryogenic thermal systems.

Part II: Applications of Cryogenic Refrigeration to Accelerators

In this part, challenges, which LBNL and KEK are doing for "Big Science in Accelerators", will be introduced.

Section A: Challenges in LBNL
LBNL is a leader in development of very high-magnetic-field superconducting magnets and is trying to upgrade superconducting magnets and helium refrigeration system.

1. A new superconducting undulator is being developed in LBNL for LCLS (Linac Coherent Light Source) II of SLAC (Stanford Linear Accelerator Center). In the undulator, it will be necessary to make a magnetic field wiggled and reduce the error of the field to get high-quality X-ray beams. To meet the requirement, an HTS (High Temperature Superconducting) corrector, which has smart switches to make correction paths of the magnetic field, is designed to operate at 20 K. A prototype of the HTS corrector is developed and tested in a cryogen-free cryostat.

2. The SuperCon group of LBNL has plans to test superconducting magnets of accelerators at 1.8 K and it is required to recover helium, efficiently. A Collins helium refrigeration system (45 L LHe/h at 4.2 K) is designed by using thermodynamic analysis. All components of overall refrigeration system considering helium recovery are determined and the economic effect is evaluated.

Section B: Challenges in KEK
In Japan, KEK is a major national organization which operates many accelerator systems and conducts training for graduate students.

1. To find out new physics, a COMET (Coherent Muon to Electron Transition) experiment is being prepared. To control high energy particles, big superconducting magnets are used and they will be subject to high irradiation. Therefore, it is necessary to cool down the magnets efficiently from two-phase forced helium and maintain them securely at 4.5 K. All of the cryogenic components are being designed from the thermodynamic point of view.

2. Big cryogenic and superconducting systems for future accelerators (ILC (international Linear Collider) and FCC (Future Circular Collider)) will have some issues about dynamics of liquid and gaseous helium in transient conditions. To estimate the helium dynamics in the large systems, a method of dynamic simulation, which considers Thermo and Fluid Dynamics, is being developed at KEK. Now, the accuracy and availability of the simulation are being evaluated as comparted with experimental results obtained from current accelerator systems.