§6. Development of a Current-Feed System with Low Heat Load Using a Pulse Tube Cooler

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In operating usual large superconducting magnets such as LHD coils, the high current of 10 kA class is supplied through current leads into the cryogenic region from a power supply located at room temperature. The heat leak from the current leads causes a large load of the refrigeration system. Therefore it is necessary to reduce the heat leak from the current leads with a minimum refrigeration load for a low cost and stable operation of the superconducting magnet system. Optimization methods have been studied for designing gas cooled current leads with copper conductor, and the heat leak into the liquid helium region is evaluated to be 1 W/kA for the optimum gas cooled current leads. Several types of high temperature superconducting (HTS) current leads were developed for further reduction of the heat leak. The HTS conductor is employed in the HTS current leads in the temperature region below ~ 50 K, while the copper conductor feeds the current from a room temperature to the HTS conductor. Although a large reduction in the heat leak has been demonstrated in the operation of the HTS current leads, large heat load to the refrigeration system is still generated in the conventional copper conductor part.

In this work, we apply advantageous characteristics of a pulse tube refrigerator to the copper conductor region of the 3kA HTS lead system for a reduction of the refrigeration load caused by with a compact structure.

Since the thermoacoustic effect is utilized for operation, the pulse tube refrigerator consists of a pulse tube, a regenerator and warm-and cold heat exchangers without moving element in the cryogenic region. Fig. 1 shows a schematic drawing of a pulse tube current lead. The copper-rod conductor is concentrically inserted into the pulse tube. In Fig. 1, geometrical dimension of the copper conductor was optimized for supplying current of 3 kA to a temperature of 80 K in the adiabatic condition. The heat leak through the copper rod is estimated to be 200 W at the cold end of 80 K. The heat leak of 200 W from the copper rod is removed by the cold heat exchanger in the pulse tube fridge. An advancing pressure wave is induced in the pulse tube by open-close operation of 4-valves. The refrigeration power is generated by the expansion-work in the cold region caused by the pressure wave. The high performance of the pulse tube refrigerator is obtained by modulating the phase of the pressure wave in the optimum inner volume of the tube. In this work, the inner volume of the pulse tube is optimized to be 650 cm^3 by employing numerical analysis of the dynamics of a virtual gas piston in the pulse tube. The cooling power is estimated to be 196 W at 80 K.

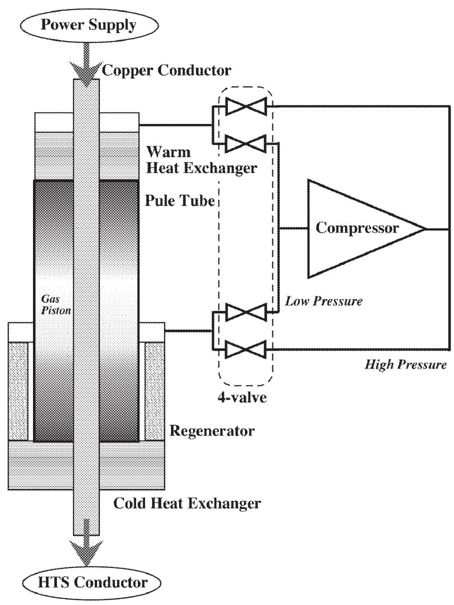

Fig. 1 Concept of the pulse tube current lead.