SRF CRYOMODULE AND CRYOGENICS DEVELOPMENTS FOR THE NEW LIGHT SOURCE

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Abstract

The superconducting LINAC for the proposed New Light Source (NLS) project in the UK, will consist of 18 cryomodules operating at 1.8 K, each having 8, 1.3 GHz cavities operating in CW mode. The cryomodule design and cryogenic distribution scheme will be some of the key elements to achieve the desired performance of the superconducting RF (SRF) linac. Around the world, several large scale facilities (based on SRF linacs) are already operating (for example – CEBAF, SNS, FLASH) and several more have been proposed (XFEL, ILC, Cornell ERL, etc.). In this paper we define the requirements of the NLS cryomodule, adopting proven L-band technology systems and also describe the cryogenic distribution scheme, in order to develop an effective and economic solution for the NLS.

INTRODUCTION

XFEL cryomodule (CM) design is chosen as a reference to develop a suitable cryomodule for the NLS-LINAC [1]. However due to CW operation the dynamic heat load experienced by the NLS-CM will be higher than the XFEL-CM [2] by about an order of magnitude, See Table 1. Consequently the XFEL-CM must be modified to handle much higher mass flow with much higher helium-gas pressure stability at lower operating temperature of 1.8 K. A conceptual engineering design incorporating necessary modifications has been developed, some of which are illustrated in this paper. More comprehensive details will be discussed in the CDR for the New Light Source to be published later [3].

Cryogenic distribution is one of the most complex tasks in the development of a large accelerator. Successful operation of several large scale cryogenic systems, for example, CEBAF, LHC, SNS etc. has already been demonstrated, but no common guidelines can be derived for the development of a new system as the requirements vary widely which depend upon several factors for example: overall length of the accelerator, mode of operation (pulsed or CW), helium mass flow rates, time scales, funding etc. We undertook a preliminary study of the cryogenic distribution schemes for some of the key accelerator projects to work out an appropriate strategy for the NLS. This also will be discussed in the second part of the paper.

CRYOGENIC HEAT LOADS

Table 1 gives the estimates of the heat load for a single cryomodule of NLS. Heat load for XFEL is also included for comparison. Due to the CW operation the dynamic heat load experienced by the NLS cryomodule will be about 10 times higher than the XFEL variant. Consequently the XFEL cryomodule must be modified to handle much higher mass flow with much higher helium-gas pressure stability at lower operating temperature of 1.8 K. Some of these requirements were analysed and identified during an industrial study [4] to develop a suitable cryomodule solution for the BESSY-FEL project; the requirements for which were similar to NLS. In order to address all the related issues, a conceptual engineering design has been developed incorporating all these changes as described below, but more work is required to guarantee optimum performance.

Table 1: The static and dynamic heat load (in W) of one cryomodule with 8 SRF cavities at an accelerating gradient of 15 MV/m, Q= 2 x 10^{10} operating in CW mode.

Source	Static	Dynamic	Total NLS	Total XFEL
1.8 K	16.0	96.2	112.2	11.1@ 2K
5K-8K	13.5	8.0	21.5	28.1
40K-80K	63.9	88	151.9	113.8

MODIFICATIONS TO XFEL CRYOMODULE

Several modifications to XFEL cryomodule have been identified. Figure 1 shows some of the key modifications made to the XFEL cryomodule.

Larger Two Phase Line

To allow the heat transfer at 1 W/cm^2 with a pressure drop of less than 0.1 mbar across the length of the cryomodule. The diameter of the two phase line and the pipe connecting the cavity reservoir and the two phase line has been increased from 88 mm to 100 mm

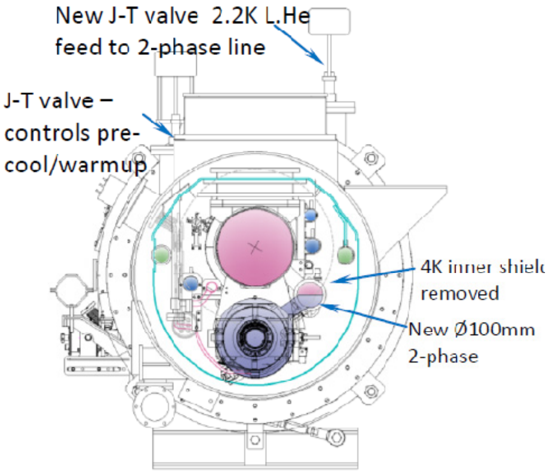

Figure 1: Cross section of a NLS cryomodule.

Removal of the 5 K Thermal Shield

Increase in the two phase line conflicts with the 5-K shield and one way to resolve this conflict is to remove this thermal shield. The absence of the 5-K shield will increase the static heat load for a cryomodule by approximately 3 W. This is only a fraction of the total dynamic load of 110 W and will have negligible impact on operation of the LINAC and the cryoplant capacity. Similar approach has been proposed for BESSY-FEL, CORNELL-ERL [5] as well as for ILC [6]. However the 4-K to 8-K cooling circuit will still be required for introducing thermal intercepts for the RF couplers and several cryostat-support components. Primary reference designs of the additional thermal links have been developed and more work is needed to verify the performance.

Integrating Two Cold Valves for Each Cryomodule

In order to handle the increased mass flow (~10 g/S per cryomodule) at a lower operating pressure of 18 mbar, two cold valves will be introduced in every cryomodule; one as a Joule Thomson (JT) valve for 1.8 K operation i.e. for the level control and pressure stability, and the other to aid the warm-up and cool-down of the cavities as shown in Figure 2.

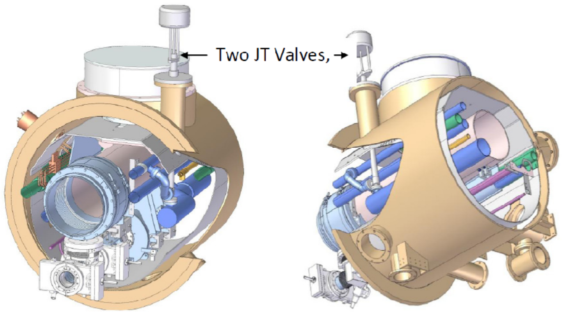

Figure 2: Two JT valves integrated into the cryomodule.

Connections to 300 mm GRP

Inserting the JT valves in the cryomodule requires that the two-phase-line and the pre-cool-line are terminated inside the cryomodule. In the case of XFEL these lines continue without break through the cryomodules without any break and are terminated only at the end of the cryomodule string. The connection between the two phase line and the 300 mm gas return pipe for XFEL-CM is also made only at the end of the cryomodule string, which in the case of the NLS must be made inside. This is now done at two places, one close to the JT valve and the other near the reservoir as shown in the Figure 3.

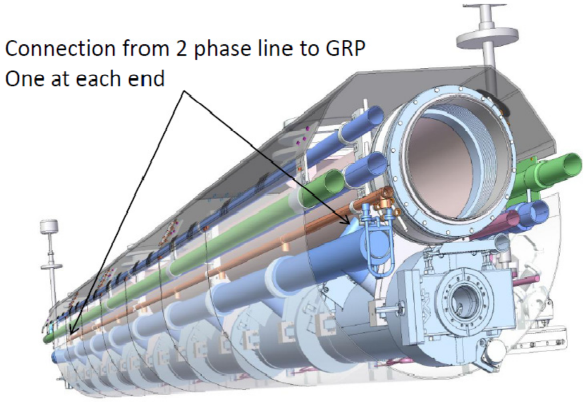

Figure 3: Connections between the two phase line and the helium gas return pipe.

External Transfer Line Sections

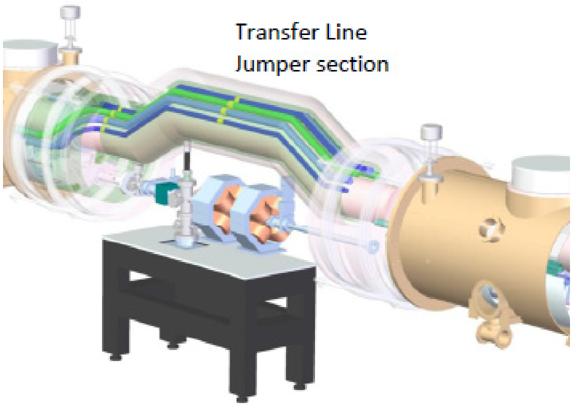

Figure 4: Transfer line jumper section connecting two cryomodules to bypass warm dipoles.

The operation of NLS LINAC requires some warm components, for example; the dipoles and diagnostic equipment, to be inserted in the beam path. The cryomodules in the NLS-LINAC are therefore divided in seven groups with 7 jumper sections of cryogenic transfer lines to maintain the continuity of the process lines throughout the length of the LINAC. The design of the jumper section will be very complex due to the accommodation of variety of cryogenic process lines at different temperatures and pressures. A conceptual

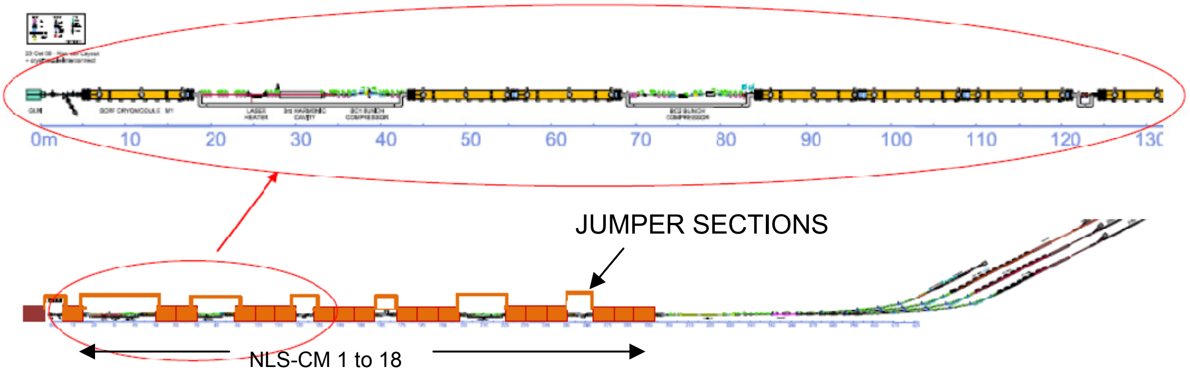

Figure 5: Cryogenic distribution for the NLS LINAC.

design of these jumpers section has been developed for modelling purposes as shown in Figure 4.

CRYOMODULE INTERCONNECTIONS

NLS-LINAC will require a large liquid helium refrigerator providing a cooling power of 3.4 kW at 1.8 K. Details of the cryogenic requirements for NLS are described elsewhere [7]. A preliminary study of the cryogenic distribution scheme of some of the existing accelerator projects was conducted. Cryogenic and vacuum sectarisation is a complex subject affecting several projects for example; project X, XFEL, SPL, ILC etc. and no clear-cut universal approach or guide lines have been established yet [8]. The choice is generally based on a sound compromise between the performance, cost and associated risks and varies widely from project to project.

CEBAF, the first CW the first CW-LINAC [9] and SNS [10], employed two sets of external transfer lines running parallel to the LINAC. This design gives full flexibility in operating or isolating any individual cryomodule. But the demountable bayonet fittings make the transfer line designs very complex and costly. Moreover the risk of gas-leaks leading to additional heat leaks makes this scheme less attractive.

XFEL [11] and ILC [12] have taken the other extreme approach of considering the whole length of the linac as a single large cryostat. The continuity in the cryogenic process lines is maintained by connecting the consecutive Cryomodules in series. No external transfer lines are used. With this approach no individual cryomodule can be isolated or removed without warming up the whole LINAC. Reliability in cryogenic operation is improved by the way of introducing very high level quality control measures at every stage, from design to commissioning.

NLS-LINAC needs several warm sections for diagnostics and beam control. The cryomodules in the LINAC are distributed in 7 sections as shown in the figure 5. The cryomodules are connected in series and the continuity between individual sections is maintained through special jumper sections (see figure 5) Two redundant cryomodules have been introduced to mitigate the risk of failure or performance degradation of any cavities in the LINAC.

SUMMARY

NLS will be based on a SRF-LINAC operating in CW mode. XFEL cryomodule is chosen as a reference design and several modifications are necessary to the design to suit the LINAC operation in CW mode. This paper describes some of the key modifications as well as a strategy for cryogenic distribution. More investigations will be required to validate the design which will be undertaken in the TDR (Technical Design Review) phase of the NLS project.

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