Development of New High Field Superconducting Magnets for Research Applications

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Abstract – Recent advances in superconducting and cryogenic technology combined with increased demand for superconducting magnets for research applications at high field (HF) are enabling the development of new generation of HF magnets. New generation of HF magnets will use advanced low temperature superconducting (LTS) materials and employ innovative coil structure solutions complemented with effective magnet quench management. This contribution presents an update on the latest generation of HF magnets for research and industry. The emphasis is on new LTS materials and the dependence of coil development on the performance of superconducting materials at high fields. Recent advances in internal Sn superconductors have opened up a new era in superconducting magnet technology. New LTS outsert magnets are undergoing development enabling high field magnets greater than 22 T using high temperature superconductors (HTS). The new magnets are compact in size with enhanced access bore.

Introduction — Research magnets are used in different science research, health, industrial and energy applications. Development of high field magnets >23 T at low temperature and superconducting magnets at >10 K will require the use of High Temperature Superconducting (HTS) materials. Oxford Instruments is developing new generation of HF wide bore magnets using new advancement in wire technology, new techniques in coil structure together with innovative energy management solutions.

In this work we report on current progress at Oxford Instruments on developing new generation of HF compact magnets with various bore sizes and field strengths that will enable studies and characterization of materials and devices using superconducting coils in steady state over long period of time enabling new science discoveries.

Critical elements for development of new HF SC magnets

<table>
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<th>Wire properties</th>
<th>High losses</th>
<th>Medium losses</th>
<th>Low losses</th>
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<tr>
<td>High I&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Distributed barrier material</td>
<td>Reduced D&lt;sub&gt;q&lt;/sub&gt; (HEP)</td>
<td></td>
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<tr>
<td>Medium I&lt;sub&gt;1&lt;/sub&gt;</td>
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<td></td>
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<td>Standard I&lt;sub&gt;1&lt;/sub&gt;</td>
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Innovative new internal tin Nb<sub>3</sub>Sn /RRP<sup>®</sup> wires used for HF magnets

SC Materials/Design
- LTS <23 T
- HTS >23 T
- Conductor design
- Filament size

Coil Technology
- Compact magnets
- Coil structure
- Cooling techniques
- Low vibration (if cryofree™)

System Integration
- Integrating coils with different wires including LTS+HTS
- Design Tools
- Quench management
- Instrumentation

Ongoing development of HF wide bore systems at OI
1. 15 T 160 mm bore
2. 19 T 150 mm bore
3. 15 T 250 mm bore
4. 18 T 150 mm bore

Current progress with 32T NHMFL HF magnet

Impact of new wires on development of HF

Selected OI standard HF magnet for research applications:
1. 18 T 52 mm Cryofree™ @4.2 K (Standard Homogeneity)
2. 20 T 52 mm bore @4.2 K (22 T @2.2 K) (Standard Homogeneity)
3. 20 T 78 mm bore @4.2 K (High homogeneity)

Summary –
- HF superconducting magnets hit the limit of LTS capabilities
- Engineering of SC magnets up to 23T (narrow bore) is well understood and can be offered commercially as standard product
- HTS materials like Bi-2212, & YBCO are available in enough lengths to develop inserts for HF (tested up to 34T!)
- New generation of HF compact magnets - different bore sizes & cooling methods
- Magnet development of HF systems >25T is now possible
- HF development strongly driven by the user community & new SC technology

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