Experimental Study on AC Loss of a Quasi-isotropic Strand Fabricated by Coated Conductors in AC Magnetic Fields

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Background

A new calorimetric method for measuring AC loss in AC magnetic field by optical fiber Bragg grating (FBG) is able to solve problems occurred in the process of conventional electric and calorimetric measurements. Since the FBG temperature sensor has advantage of rapid response and anti-electromagnetic interference, the calorimetric method based on FBG is very suitable for AC loss measurement of HTS applications in much more complicated electromagnetic circumstance due to thin geometrical sizes and optical characteristics of FBG temperature sensors.

Objectives

- AC loss calculation of a quasi-isotropic HTS strand in AC magnetic field by Comsol Multiphysics using A formulation.
- AC loss measurement of a quasi-isotropic HTS strand in AC magnetic field by a new calorimetric method using FBG.

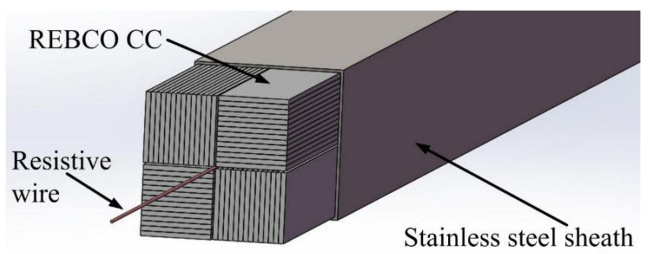
Conclusion

- The calculation of AC loss contains hysteresis loss, eddy-current loss and coupling loss. The calculated results show that hysteresis loss dominates the AC loss of the quasi-isotropic HTS strand at LN_2 temperature and power frequency.
- The response of FBG in low temperature range is measured, the measurement results indicate that FBG has good repeatability on temperature measurement around LN_2 temperature.
- AC loss of quasi-isotropic HTS strand in AC magnetic field is measured by optical sensing interrogator based on calibration between energy loss and FBG response. The measured results of AC loss are in agreement with calculated ones, which suggests that calorimetric method using FBG technique can be effectively feasible for measurement of HTS strand or cable and help us to improve understanding AC loss properties in any complicated electromagnetic environment.

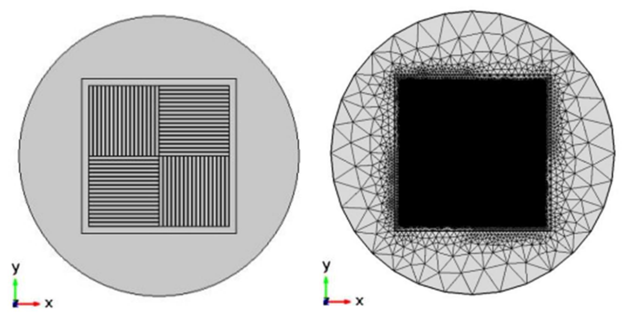
Calculation

Calculation of AC loss

AC loss of quasi-isotropic HTS strand in AC magnetic field is simulated by Maxwell's equations together with appropriate constitutive laws for the superconducting layer using A formulation.

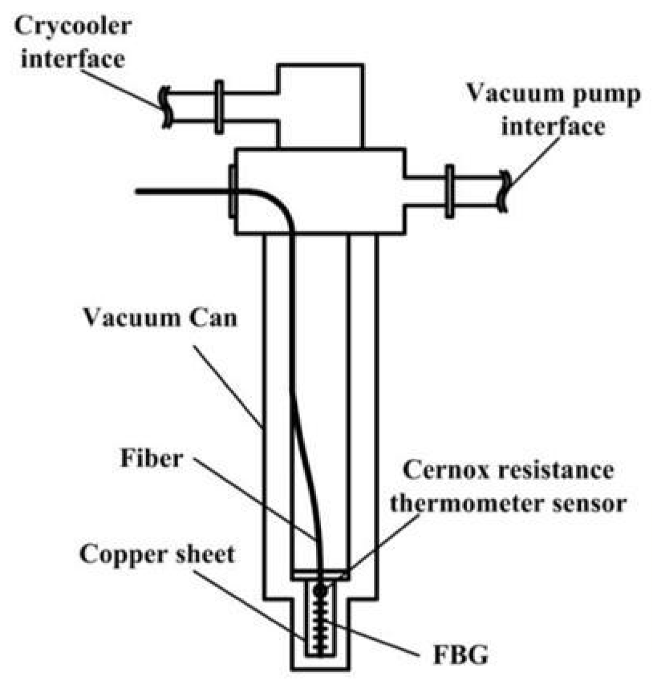


The distribution of electric field, magnetic field and current in HTS strand can be acquired by Comsol Multiphysics, the loss values can be obtained through the surface integral of different area of HTS strand.



Measurement

FBG Properties at Cryogenic Temperature

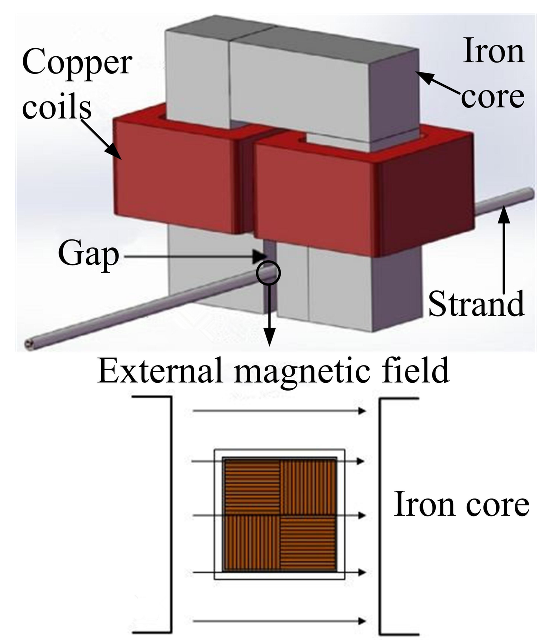


In order to apply FBG temperature sensing technology in superconducting research, it is essential to calibrate the dependence of wavelength shift on temperature for FBG in temperature range of LN_2.The experimental setup is used for maesuring wavelength of FBG on temperature.

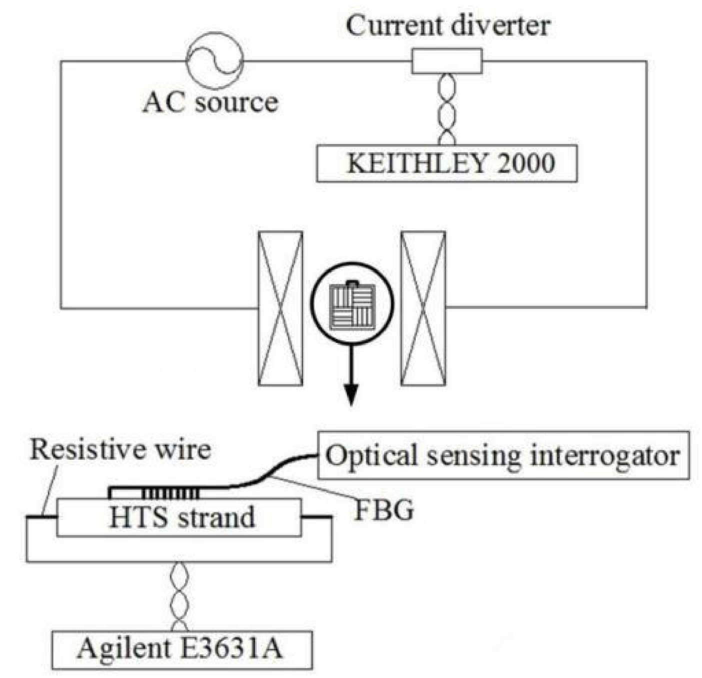
FBG is fixed on cold-head of crycooler by thermal conductive adhesive is calibrated by Cernox thermometer by cooling-down and heating-up. The wavelength of FBG is measured by optical sensing interrogator with fiber sensors system.

Magnetic Field Generator

The AC magnetic field can be generated by copper coil which locates outside of iron core. There is an air gap in the iron core which can accommodate the strand.



Measurement of AC loss

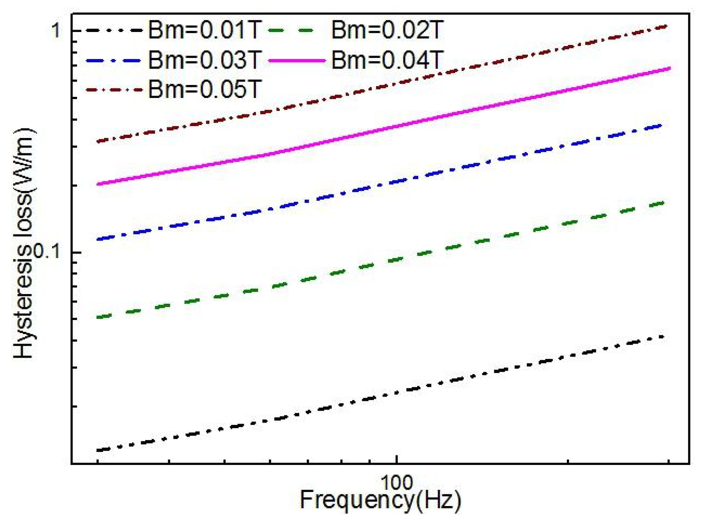


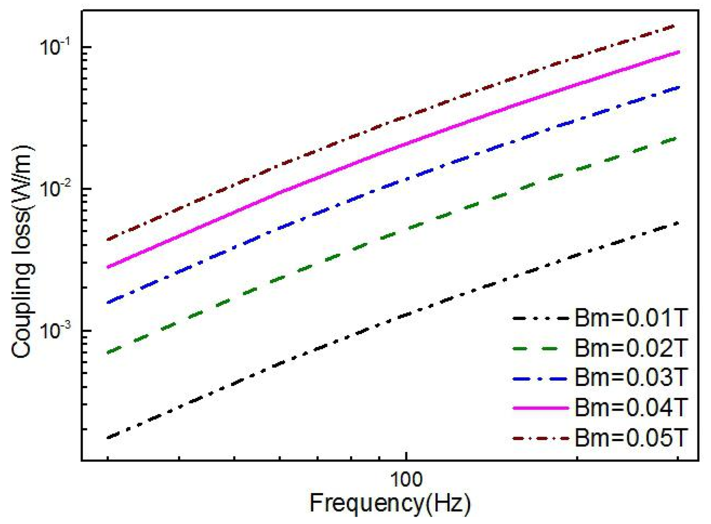
The resistive wire in the center of the HTS strand is powered by Agilent E3631A instrument, the energy loss can be obtained by E3631A. The wavelength shift of FBG owing to temperature rise resulting from the energy loss is measured by optical sensing interrogator. Then a calibration curve between energy loss and wavelength shift of FBG response is finished.The resistive wire is switched off after calibration.

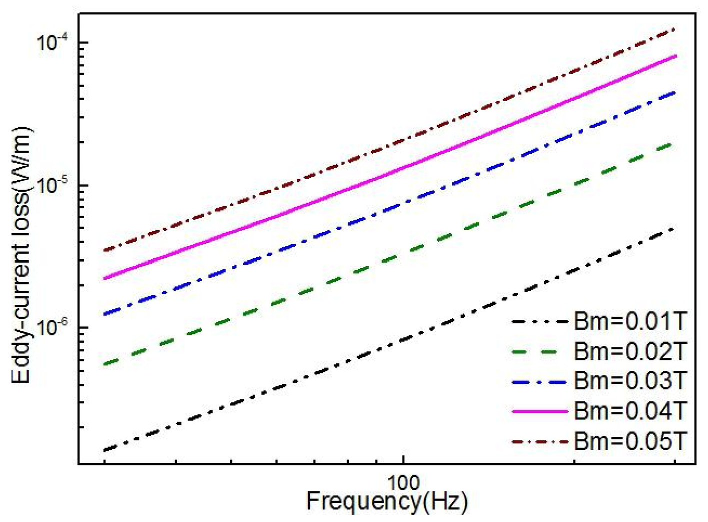
The wavelength shift of FBG and the amplitude of AC magnetic field in the gap produced by magnet can be acquired during the process of the experiment, AC loss can be obtained according to calibration of the wavelength shift of FBG and energy loss of strand.

Results

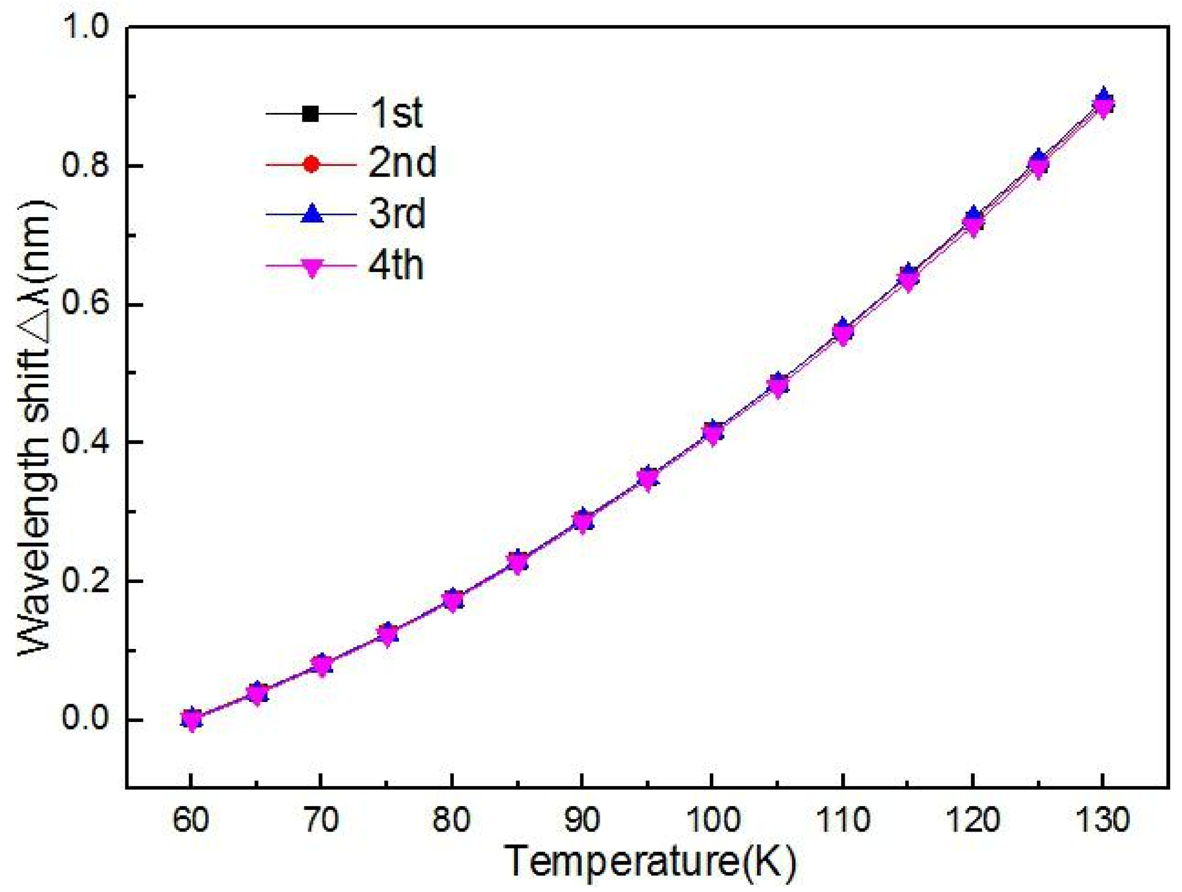
Calculated results





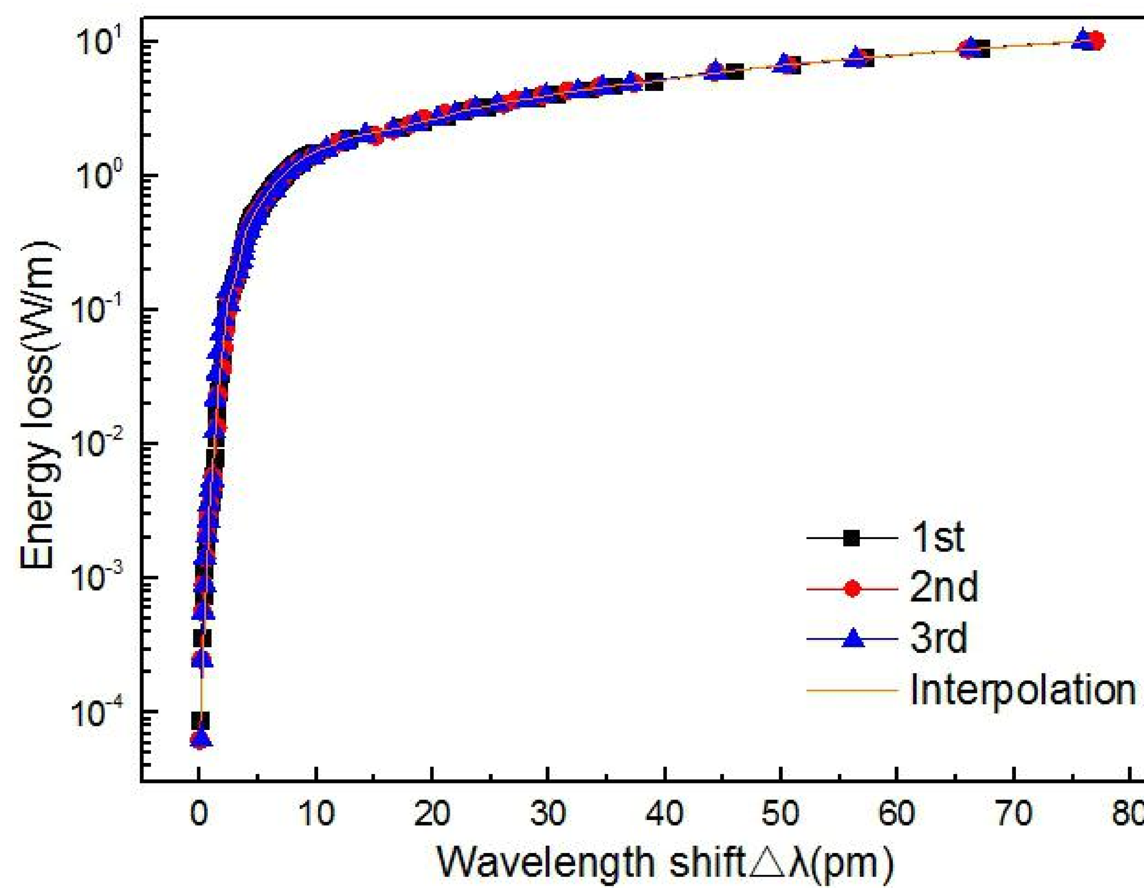


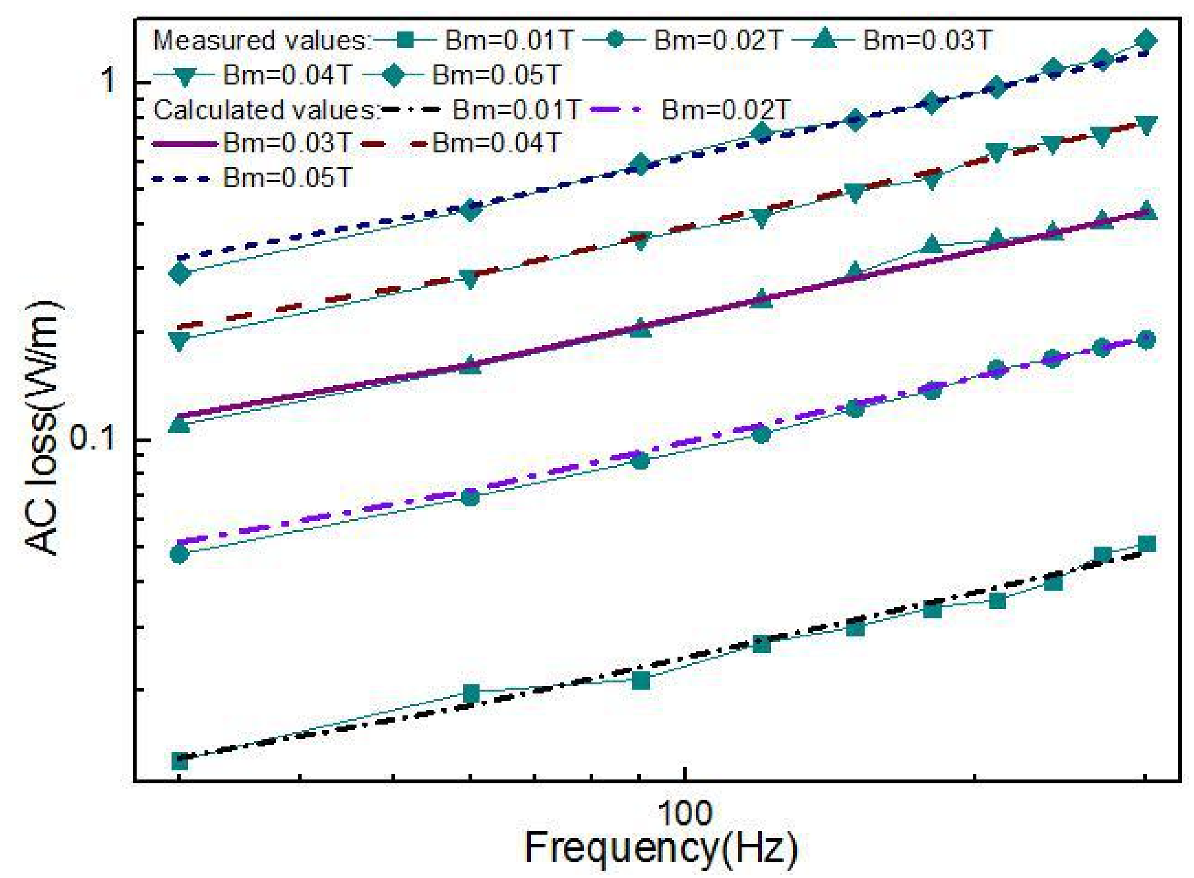
The calculated results of hysteresis loss, coupling loss, and eddy-current loss in the HTS strand illustrate the eddy-current loss and coupling loss are smaller than the hysteresis one, all of the three components of AC loss increase with the amplitude of AC magnetic flux density B_m and frequency.



The measurement results indicate that the repeatability is good enough, so the optical FBG can be used to measure temperature rise in temperature range of LN_2.

Measured results





The wavelength shift of FBG and the amplitude of AC magnetic field in the gap produced by magnet can be acquired during the process of the experiment, AC loss can be obtained according to calibration of the wavelength shift of FBG and energy loss of strand. According to comparison between calculated and measured results of AC loss, the measured results of AC loss are in agreement with calculated ones.

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