1.14 Current status and future development of neutron scattering in CIAE

D.F.Chen, C.Gou, C.T.Ye, L.P.Guo, K.Sun

China Institute of Atomic Energy, PO Box-275-30, Beijing 102413, P.R.China

Abstract

Currently, the 15 MW Heavy Water Research Reactor (HWRR) at China Institute of Atomic Energy (CIAE) in Beijing is the only neutron source available for neutron scattering experiments in China. A 60 MW tank-in-pool inverse neutron trap-type research reactor, China Advanced Research Reactor (CARR), now is being built at CIAE to meet the increasing demand of neutron scattering research in China. According to design, the maximum unperturbed thermal neutron flux would be expected to be 8×10^{14}n/cm^2.s in the reflector region. Seven out of nine tangential horizontal beam tubes will be dedicated for neutron scattering experiments. A cold source, a hot source and a 30×60 m^2 guide tube hall will also be constructed. In this paper, a brief introduction of HWRR, the existing neutron scattering facilities and research activities at HWRR, CARR, and the facilities to be built at CARR are presented.

PACS numbers: 61.12.Ex

Introduction

HWRR is a 15 MW Multipurpose Research Reactor at CIAE, and is also the unique neutron source available for neutron scattering experiments at present in China. It was put into operation in September 1958, and was upgraded in June 1980. Since HWRR has been operated more than 40 years and it will be decommissioned soon, the project of establishing a 60 MW China Advanced Research Reactor (CARR) in CIAE has been approved in 1999. It will be expected that CARR will become critical in 2005.

1. Current neutron scattering status at HWRR

After upgrading in 1980, the maximum power of HWRR increased from 10 to 15 MW and the maximum unperturbed thermal neutron flux also enhanced to 2.8×10^{14}n/cm^2.s in the core. 4 out of 6 radial horizontal beam tubes are used for neutron scattering experiments. In 1987, a liquid hydrogen (LH_2) cold source of Φ 110 mm$\times$50 mm volume was inserted into the beam tube to keep the moderator temperature at about 21K. A 32 m guide tube (27 m bent plus 5 m straight guide) installed at the end of the cold beam tube, transporting cold neutron beam to an experiment hall next to HWRR building. At present, six neutron scattering facilities are installed at 4 beam tubes: Powder neutron diffractometer, Four circle diffractometer, Triple axis spectrometer, Double-chopper time of flight spectrometer, SANS spectrometer with a 64 $\times$64 elements ^{3}He position sensitive detector and Be-filter wide angle detector spectrometer. In recent years, various neutron scattering investigation on static structure and dynamic information of various materials, such as permanent magnetic materials, High – Tc superconductors, non-linear optical material and biology samples, etc[1-11].

2. Main features of CARR

Same to HWRR, CARR will also be a Multipurpose Research Reactor for the neutron scattering research and other applications, such as , radioisotopes production, neutron transmutation doping silicon, neutron activation analysis, etc. CARR will be a tank-in- pool inverse neutron trap type reactor with nuclear power of 60MW with maximum unperturbed thermal neutron flux of 8×10^{14}n/cm^2.s. 7 out of 9 tangent horizontal beam tubes are used for thermal neutron scattering experiments, some of them have two beam outlets. Both cold and hot sources will be installed at CARR, The temperature of liquid hydrogen cold source will be around 20 K, and cold neutron (4 ~ 20 Å) gain factor can reach more than 10. The temperature of graphite block hot source will be about 2000 K and the hot neutron (0.4 - 0.8 Å)

gain can reach the factor of ~15 at 0.5 Å. Two hot neutron beams can be provided. Most of the instruments at HWRR will be upgraded and moved to CARR to continue employing. A triple axis spectrometer, a four circle spectrometer, a time of flight spectrometer, a rebuilt texture powder neutron diffractometer, a new multi-purpose hot neutron beam spectrometer and a new high resolution powder diffractometer will be placed in the reactor experiment hall. The SANS will be installed at the exit of the nature Ni guide in the Guide hall. A horizontal scattering geometry polarized neutron reflectometer will be constructed and accommodated at guide hall using cold neutrons from the Ni-58 (or supermirror) guide tube. Four guide tubes with beam cross section of 30mm×150mm can be put into the cold beam tube for transporting the cold neutron beams to a $36\times60m^2$ guide hall . Two of them, the nature Ni coated and the Ni-58 coated (or supermirror) , are planned to come in use soon after CARR becomes critical. The other two neutron guides will be installed in the future.

3. The features of neutron scattering instruments at CARR

High - resolution powder diffractometer (HRPD) is a new instrument. Ge vertical focusing monochromator provides incident neutron wavelength λ=0.8~2.9 Å. The resolution $\Delta d/d$ is 0.2%. The multiple detector system consists of 64 ^{3}He counters. The 2θ range is 5^0~160^0; Neutron reflectometer (NR) is another new instrument . The monochromator is made of vertical focusing Ge(111) or Ge(311), and the incident neutron wavelength is 2.5 ~4.5 Å. The resolution $\Delta\lambda/\lambda$ is 0.01. The Fe-Si supermirror will be used for neutron polarizor and analyzer. The detector system includes a $20\times20cm^2$ two dimension detector for 0~5° 2θ measurement and single ^{3}He counter for high Q measurement . When 2θ of the ^{3}He counter are as high as 130° , the Q_{max} is around 4.5 $Å^{-1}$; Multi-purpose Spectrometer (MPS) is also one of new instruments. The same monochromator is used by three instruments: two axis diffractometer, triple axis spectrometer and Be-filter detector spectrometer. The monochromator support carries three different monochromators (Cu (111), Cu(220), Cu (331)) . The incident neutron energy range is 10~1000meV. The $2\theta_M$, $2\theta_A$, $2\theta_S$ ranges of

triple axis spectrometer are 18~90°, -120~120°, -150~150° respectively. One dimension position sensitive detector is used for two axis diffractometer. The 2θ range of the two axis diffractometer is10~128°, and the Q range is 0.3~20 Å^{-1}. For Be-filter detector spectrometer, the filter consists of 21 rectangular Be blocks, and the detector system is made of 16 ^{3}He counters. The scattering angle range for sample is 75~105°; energy resolution, ΔE/E, is 4~9%; Small angle neutron scattering spectrometer (SANS) is an upgraded instrument . The mechanical velocity selector is used for getting the neutron incident wavelength in the range of 4.5 ~ 20Å. The Δλ/λ is near 13% for standard incident wavelength 6 Å. The resolution unit is 1cm ×1cm for the ^{3}He 64×64 elements two dimensional position sensitive detector. Q range is 0.003~ 0.1 Å^{-1}; Texture neutron powder diffractometer (TNPD) is a rebuilt instrument from the old powder diffractometer. The Cu(220) and Ge (111) will be served as monochromators. The incident neutron wavelength range is 0.8~2.5 Å. The φ, χ, ω, and 2 θ ranges are -360~360°, -360~360°, -46~46°and-20~150° respectively. ^{3}He counters are used as detectors; Triple - axis spectrometer (TAS) will be improved. The monochromator includes three different single crystals (PG (002), Cu(111), Cu (220)) . The incident neutron wavelength range is 0.6~ 4 Å. The ΔE/E is changeable, and the typical value is 5%. The analyzer is a PG (002) single crystal. The $2\theta_M$, $2\theta_A$ and $2\theta_S$ ranges are 15~80°, -150~150° and -150~150° respectively. ^{3}He counters are used as detectors; Four - circle diffractometer (FCD) will be also improved. The monochromators Cu (311), Cu(111) and PG (002) will be used. Incident neutron wavelength is 1~2 Å. The ω, χ, φ and 2θ ranges are -10~75°, -20~250°, -179~179° and -10~150° respectively. ^{3}He counters are used as detectors; Double-chopper time of flight spectrometer (TOF) is also an upgraded instrument. The two choppers are background chopper and Fermi chopper, and PG and Cu single crystal will be used as monochromators. The incident neutron energy will be 5~ 200meV and the energy resolution, ΔE/E, is 2.5~ 5%. The scattering angle range of the 64 ^{3}He detectors covers 10^{0} ~ 100^{0}.

Acknowledgement:

We would like to acknowledge the contribution made by J.Z.Li, Z.X.Cheng, T.H.Yang, B.S.Zhang, H.L.Du. Y.J.Xue, K.Sun, H.L.Wang and J.He for providing helpful suggestions and supports.

Reference:

1 D.F.Chen, C. Gou et al. J.Phys: Condens. Matter 10, 255 (1998)

2 C.Gou, D.F.Chen et al. J.Phys: Condens. Matter 7, 837 (1995)

3 C. Gou et al. J.Magn.Magn.Mater 128, 26 (1993)

4 W.Mao et al. J.Phys: Condens. Matter 10, 2611 (1998)

5 W.Mao et al. Solid State Commun 107, 307 (1998)

6 X.S. Wu et al. J.Phys: Condens. Matter 8, 3647 (1996)

7 X.S. Wu et al. Physica C 282-287, 833 (1997)

8 J. H. Ruan et al. Physics letters A 187, 107 (1994)

9 J. He et al. Atomic Energy Science and Technology 31, 168 (1997) (in chinese)

10 Z. Cheng et al. Z.Kristallographie 211, 221 (1997)

11 Z. C. Lu et al. Physica B 213&214, 532 (1995)