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Recent status of a cold neutron disk chopper spectrometer, AMATERAS

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Abstract. Recent issues of a cold-neutron disk-chopper spectrometer AMATERAS are reported. Five years have been passed since we had the first neutron beam on AMATERAS. The user program is running steadily since after the visiting of the first user in 2009. In parallel to that, machine studies and commissioning works to improve spectrometer performance have been continuously done. Effort has been done on fixing the beam-transport problem, which causes the serious intensity loss at the sample position. After replacing 8.6 m section of super mirror and re-doing the mirror alignment, a part of intensity has been recovered, while still some of problems are remained. We also spent effort on reducing background caused by several sources. Study on the background sources and implementation of countermeasures are progress.

1. Introduction

AMATERAS (Figs. 1 and 2) is a cold-neutron multi disk-chopper spectrometer at Materials and Life Science Experimental Facility (MLF) at J-PARC. By using a pulse shaping chopper and owing to the high peak intensity from a coupled moderator source at MLF, AMATERAS is designed to realize high intensity and fine and flexible energy resolution measurements in quasielastic and inelastic neutron scattering experiments from cold to thermal neutron energy region [1, 2]. The spectrometer has had the first neutron beam in May 2009 and had the first user in December 2009. In parallel to the user program, machine study and technical works to maintain and to improve spectrometer performance have been continuously done. Since the last ICANS meeting held in 2012, replacement of a defected parts (a disk of one of high-speed disk choppers, a gas-leaked detector tube and other electronic parts in DAQ system), upgrading and improving of spectrometer components,

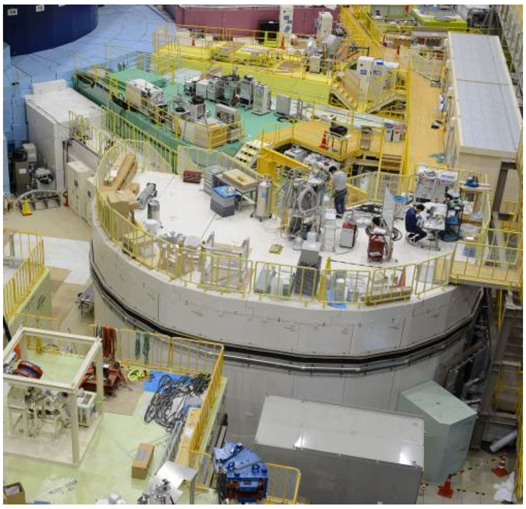

Figure 1. Recent photo of AMATERAS.

development of data analysis method and commissioning of N_2 beam monitors, newly introduced sample environments (an oscillating radial collimator, a furnace, cryostats, a 7T cryomagnet (one of MLF common accessories) and so on) have been done. Especially, we have done refurbishment of the beam transport section to solve an issue of a serious intensity loss at the sample position. Also, there is progress in the work of reduction of background, which is caused by several sources in the case of AMATERAS.

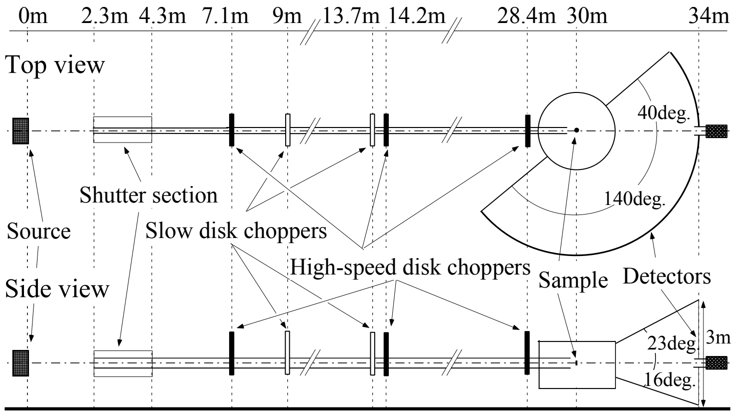

Figure 2. Schematic view of AMATERAS. Cited from Ref. [3].

2. Refurbishment of the beam transport

2.1. Overview of AMATERAS beam transport and its issues

The beam transport of AMATERAS is described in Fig. 3 [2]. The beam transport consists from *m*=3.0 and 3.8 super mirrors. The horizontal geometry has curved section (R = 2,000 m) between 7.2 m and 26.8 m from the source [1, 2, 4].

The vertical geometry is combination a straight section, an elliptical section, and a transition section between the straight and elliptical parts [1, 2, 3, 5]. Actually, the beam transport is combination consists of 28 tubes of straight and linear-tapered super mirror guides (Fig. 4 (a)). One or two tubes (each length is 0.35 ~ 2.0 m, typically 1.0 m) are set in a stainless steel vacuum jacket (Fig. 4 (b)). After aligning each tube in jackets by using push pins and adjusting screws, all jackets were set into supporting flames (Fig. 4 (c)), which have adjusting mechanisms for the jackets. The jackets were connected with formed

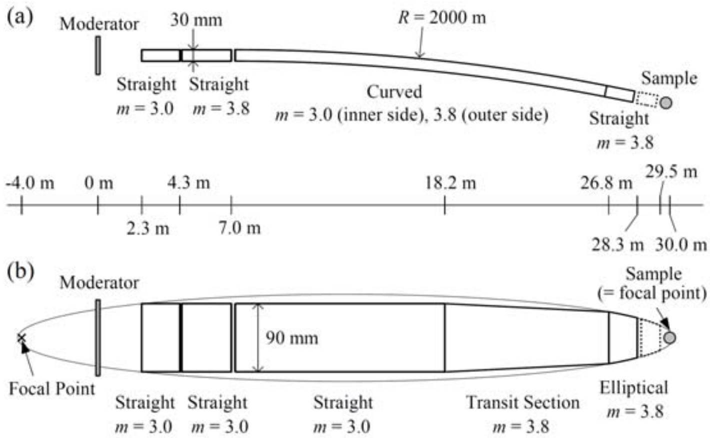

Figure 3. Schematic view of beam transport of AMATERAS (horizontal (*upper panel*) and vertical (*lower panel*) geometries). Cited from Ref. [2].

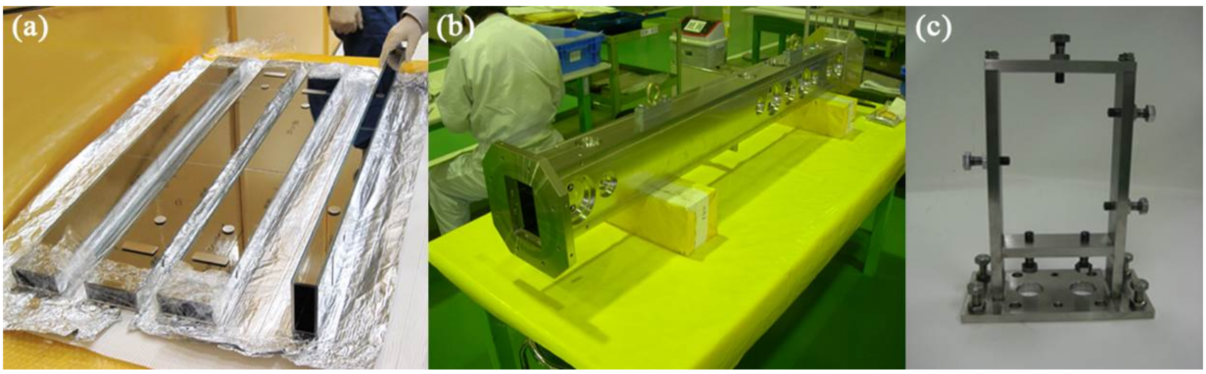

Figure 4. (a) Super mirror guides, (b) a guide jacket and (c) a support flame of AMATERAS.

bellows after alignment (Fig. 5).

In very early stage of the spectrometer commissioning, we realized that the neutron flux at the sample position is less than the expected value estimated from Monte-Carlo (MC) simulation [2]. There are three possibilities of sources of this problem, i) problems in the mirror aliment, ii) problems in the performance of super mirrors and/or iii) problems in our Monte-Carlo simulations. Soon after realizing poor performance of the intensity, we inspected the alignment of mirrors at a part (9.4 m ~ 13.4 m from the source) of the beam transport and found one of vacuum jackets rotated unexpectedly in the horizontal plane. Also, degrees of rolling of sections were deviated from values which were recorded in the installation. These evidences indicated that the mirrors were moved from original positions.

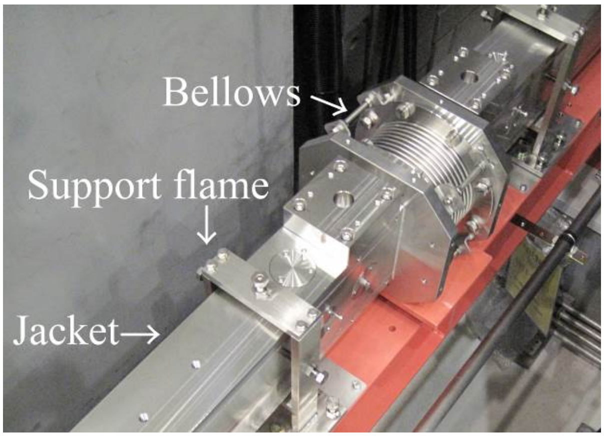

Figure 5. A connection between two jackets.

Another plausible source of the intensity loss was performance of super mirrors. In 2012, we were reported that borofloat-glass substrate super mirrors used in AMATERAS could have poor performance. In the AMATERAS's case, because of poor pre-treatment of glass surface, the reflectivity could be less than 40%, which was expected more than 80% in the specification document. AMATERAS uses suspected mirrors in the sections at 18.2 m and after from the source. Unfortunately, we did not inspect these parts of mirrors, because time schedule of construction was too tight when we installed them. To examine this possibility, we replaced 1.3 m section of tubes at the most downstream position, which we can easily access to, with well characterized mirrors (*m*=3.6, reflectivity is 65% or more). We found the intensity gain of about intensity gain of 5% which is small at the long wave length region and is large at the short wave length region. That observation is consistent if the original mirror of the reflectivity was 40%.

2.2. Refurbishment of AMATERAS beam transport

From the evidences described in 2.1, we decided to carry out a major refurbishment of the beam transport of AMATERAS. The refurbishment plan contained i) replacement of all borofloat glass super mirrors and ii) re-alignment of all beam transport at downstream of a biological shielding. Also, iii) we remade the supporting flames increasing thickness of steel plates to make them firmer, and replaced formed bellows between jackets with more soft welding bellows to reduce the tension between jackets. These are counter measure against unexpected moving of mirrors.

We purchased new mirrors in JFY 2012 from Mirrotron Ltd. Fabrication of new support flames and bellows were done consequently. Replacement and re-alignment of mirrors were carried out in long shut down period of J-PARC in 2013. In July 2013, we removed the top and side of beam line shielding. Alignment of the beam line using new mirrors, new support flames


Figure 6. Re-alignment work at AMATERAS.

and new bellows was done in November 2013 (Fig. 6, 7). After the refurbishment, positions of vacuum jackets were measuring by using a laser tracker and were recorded.

2.3. Results and remaining problems

After the large refurbishment, in February 2014, we checked the neutron flux at the sample position by measuring incoherent scattering from vanadium and by measuring inelastic and quasielastic scatterings from several samples, which were measured on AMATERAS before. We observed substantial increase of the intensity. At long wavelength region, intensity after refurbishment was 20% higher than that of before and, at higher energy region, it became almost twice (Fig. 8). The absolute intensity at the sample position, however, is still lower than the MC simulation results, which may imply that we should more seriously consider the 3rd possibility, i.e. the validity of our MC simulation calculations done before the construction. Another remaining problem is that we found the drop of the intensity very recently. We are afraid that jackets or mirrors in them may be moving. We are watching the intensity change of AMATERA carefully and are planning to open the beam line shielding in the next shut down to check the alignment.

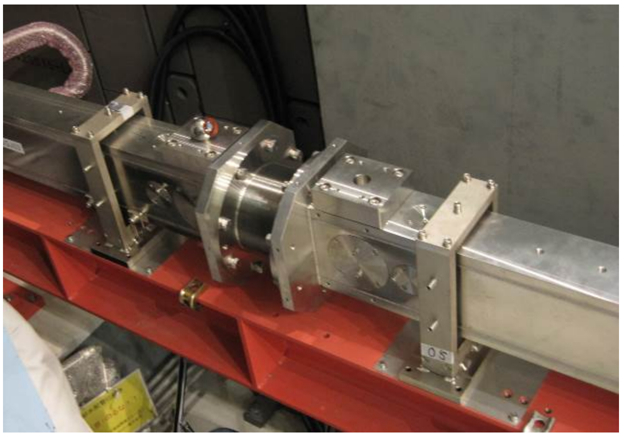

Figure 7. A photo of the same part shown in Fig. 5 taken from the opposite side after the refurbishment. One can see that designs of support flames and a bellows have been changed.

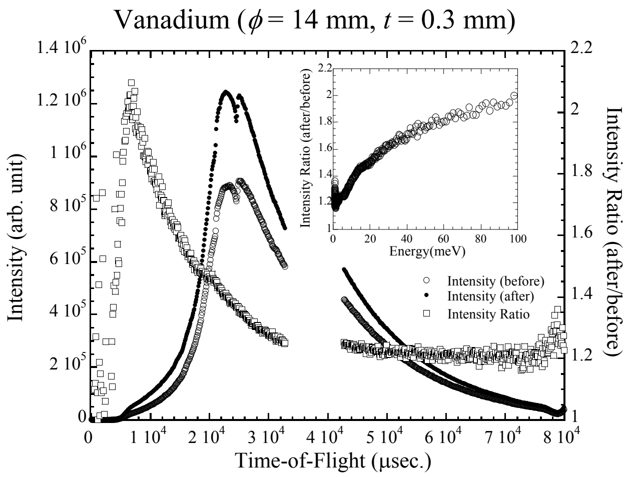

Figure 8. Scattering intensity from vanadium cylinder (ϕ = 14 mm, t = 0.3 mm) before/after the refurbishment of the beam transport. Intensity ratios are also shown.

3. Backgroun issues

3.1. Background at AMATERAS

Background (noise) is always critical to inelastic spectrometers. Reducing background is one of the highest priority issues of me as it is in the case of usual spectrometers. To minimize the background, AMATERAS i) employs a curved section in the beam transport to eliminate γ-ray and fast neutrons from the source, ii) void of inside of the beam line shielding is minimized by putting concreate blocks, steel plates and

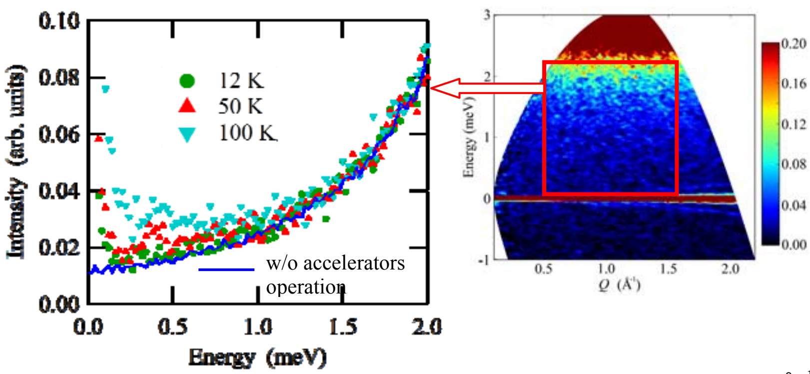

Figure 9. Energy dependences of Q-integrated (0.5 < Q < 1.5 Å^{-1}) intensities from magnetic powder sample. Results at three different temperatures are shown together with the data measured when J-PARC accelerators were stopped (solid line).

polytrimethylene blocks, iii) the inside of the shielding of the hatch which accommodates a scattering chamber is covered with B_4C contained (25wt%) precast concrete (t = 35 mm) and iv) the inside of the scattering chamber is covered with Cd plates (t = 0.5 mm). As results of these efforts, current background level (except that from samples) in the experiments on AMATERAS is 30 Count h^{-1}PSD^{-1}m^{-1}, which is time independent. One of examples is shown in Fig. 9. We are also suffered from another type background. It happens within short time range and simultaneously illuminates all pixels of detectors. As results, flat and Q-independent false inelastic signals are observed (Fig. 10).

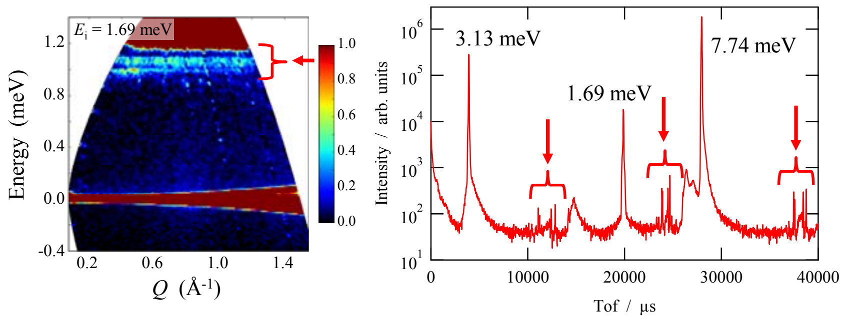

Figure 10. False signals observed at AMATERAS. Q-independent signals around 1.0 meV in the left panel is resulted from short-time signals (backgrounds) indicated by arrows in the right panel.

3.2. Time-independent background

One can see in Fig. 9 that the time-independent background counts at AMATERAS do not depend on whether the accelerators are in operation or not. The evidence implies origins of these counts are suspected to be electric noise of DAQ system and/or from environment radiations. By increasing the lower-level discrimination (LLD) (Fig. 11) or decreasing applying high-voltage (HV), we confirmed that the time-independent background. However, we are cautious about changing DAQ parameters, since changing the LLD higher than the optimized level causes decrease of the counter efficiency and decreasing HV causes decrease of the counting rate. About the environmental radiation background, most of parts come from the floor under the scattering chamber (Fig. 11(b)). As a series of tests, we put polytrimethylene and boracic acid bags under the scattering chamber. We found boron contain material is effective to reduce the background. Therefore, now we are preparing B_4C tiles to cover the floor of under the scattering chamber.

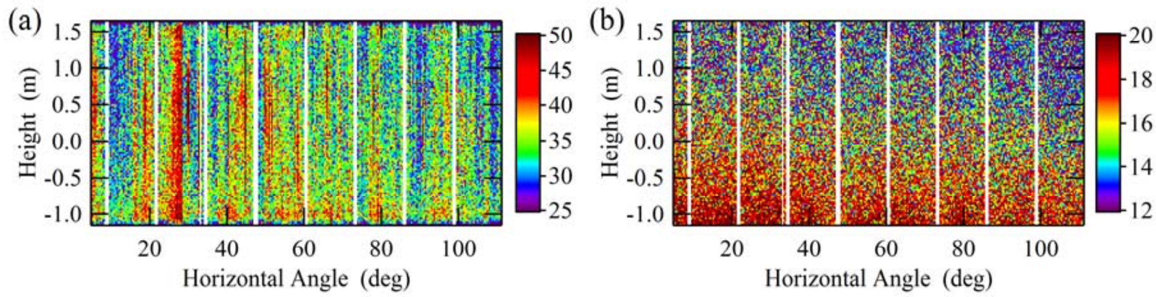

Figure 11. Intensity maps processed using (a) normal LLD and (b) 195% higher LLD. Measurement was done when J-PARC accelerators were stopped. The scale is counts/hour.

3.3. Short-time background

About short-time background, by analysing time-of-flight and flight path length we spotted the source of false signals. We converted the observed times of false signals into the flight path lengths from the source. These positions correspond to the position of a Cd window, B_4C beam narrowers and the sample position. We suspect that neutrons arrived at these positions emit γ-ray, which travels speed of light and causes noise to ^{3}He counters. There are so many Cd plates and B_4C near and around AMATERAS beam line. We are planning to replace those which possibly have direct neutron beam with other materials, for example, ^{6}Li.

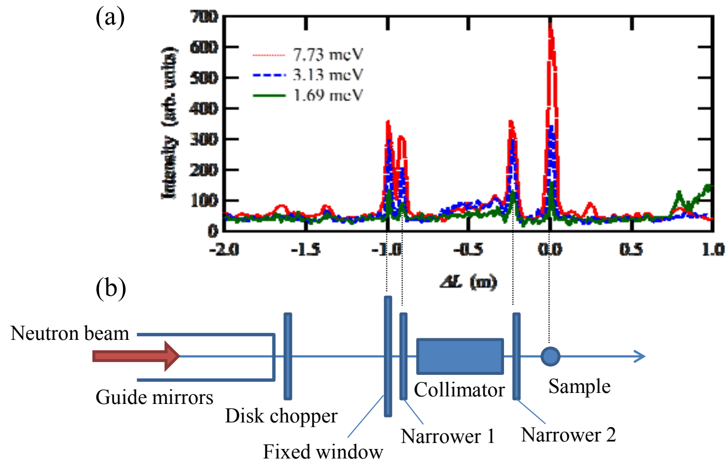

Figure 12. Time-of-flights of false signals are converted into the flight distances (ΔL = (flight path length from the source) -30 m)

4. Summary

A cold-neutron disk-chopper spectrometer AMATERAS is running steadily since its starting operation in 2009. We are continuously working on improving and upgrading the spectrometer. Recently, we have been worked on improving the beam-transport performance and reducing background, which need our further efforts.

Although there are remaining items to be improved, the user program on AMATERAS is running successfully since after the visiting of the first user in December, 2009. Until June, 2014, 61 proposals have been carried out, which have resulted more than 20 papers, 5 theses and nearly a hundred of presentations at scientific meetings. Among of them, unique data analysis methods fully utilize unique futures of AMATERAS were developed [6]. Recently two press releases were issued on studies on biology [7] and magnetism [8]. In December 2014, AMATERAS had an interim assessment by neutron instruments review committee of MLF, J-PARC, which all instruments at MLF are obliged to have after 5 years their operations. AMATERAS had positive assessment, and committee recommended continuing AMATERAS project for next 5 years.

We are continuing to spend effort to improve performance of AMATERAS to produce further scientific results from this spectrometer.

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