External Evaluation of Neutron Science Division (KENS) within the Institute of Materials Structure Science at KEK

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- **Executive Summary**

  The instruments are competitive with those at ISIS and SNS, in terms of technical specifications and physics performance. The J-PARC source is now running at sufficient power, and a reasonable number of days per year. The number of operating days is comparable with those at ISIS and SNS, and the instruments are of similar quality.

  We note that the average ratio of staff per instrument (excluding postdocs and students) is just above 3:1 at KENS, whereas the world-standard is 6:1, if one wants to run a full-service user program for ~200 days per year. This is the historic standard at the Institute Laue-Langevin (in Grenoble, France) and at ISIS (near Oxford in the UK), and it is achieved at the OPAL Research Reactor (in Sydney, Australia). We do not believe that KENS (or the MLF, for that matter) can be fully research competitive with ISIS, SNS and the leading research reactors, unless this major handicap is rectified.

  We strongly support the idea of harmonizing the user access regime (and support levels) across the KEK and JAEA instruments at J-PARC.

  In general, the quality of research performed by KENS (and done on KEK's instruments at J-PARC) is high, is published in very good journals, and receives international recognition. There is a good array of international connections, both in terms of overseas users of the instruments, and of KENS staff using other facilities when necessary.

  However the volume of research is low compared with other facilities, particular in America, and particularly in powder diffraction. We strongly urge the KEK management to try to diagnose the underlying causes for this discrepancy, and to rectify it, if they can.

- **Evaluation of present status of KENS**

  The KENS is equipped with 8 internationally competitive neutron instruments. Considering the limited budget and fairly low staff members, compared with other facilities such as ISIS and SNS, KENS is doing a very good job. However, there is a large room for improvement, which absolutely requires additional budget and staff members.

  As far as we can tell, the operation of KENS is consistent with the Japanese Government's definition of an "*Inter-University Research Institute Corporation*", which is itself not so different from how most other leading international neutron-scattering facilities are run, aside from the fact that J-PARC has a very complicated multi-party management system (i.e. KEK, JAEA, Ibaraki University and CROSS).

- **Evaluation of instrument performance**

  There are two aspects to instrument performance: (a) the actual technical specifications and physical performance, i.e. how good are the instruments? And (b) the scientific productivity of each instrument, in terms of demand, user satisfaction and the number and quality of papers produced.

  Technical performance:

	SHRPD	**NOVA**	**SPICA**	**HRC**	**SOFIA**
Flux on sample	Comparable with SNS and ISIS	>> ISIS < SNS	Comparable with SNS and ISIS	Not benchmarked	Not benchmarked
Resolution	Comparable with SNS and ISIS	Comparable with SNS and ISIS	Better than iMATERIA; comparable with POWGEN	Comparable with SNS and ISIS	Comparable with, or better than, SNS and ISIS
Dynamic Range	Comparable with SNS and ISIS	Comparable with SNS and ISIS	Comparable with SNS and ISIS	Comparable with SNS and ISIS	Comparable with SNS and ISIS
Solid angle of detector	Not benchmarked	Comparable with SNS and ISIS	Not benchmarked	Smaller than 4SEASONS, ARCS and MERLIN	sufficient
% of detector complete	90%; 67%; 100%	73%	100%	57%	100% of relevant solid angle
Other					R_{min} of 10^{-8} is state-of-the-art

  Research productivity:

  Of the 4 KENS instruments (**SOFIA, HRC, SHRPD** and **NOVA**) that have been operating for many years, we have benchmarked the number of refereed research papers resulting from beam time on them, against similar instruments at ISIS and SNS.

The **SOFIA** reflectometer is producing at a world-competitive rate. An average of 15 papers per year is typical for reflectometers at other neutron sources. By some measures, SOFIA is the most research productive instrument at the MLF.

The **NOVA** liquids/glass diffractometer is competitive with the two similar instruments at ISIS, but all three of these instruments significantly underproduce compared with the NOMAD diffractometer at SNS (Oak Ridge), by a factor of 3 or so.

The **HRC** chopper spectrometer (and the 4-SEASONS instrument, also at J-PARC) produce papers at a similar rate to the 2nd-tier instruments at ISIS, but fall well behind the SNS instruments and the flagship ISIS instrument, by a factor of 4 or so.

The high-resolution powder diffractometer **SHRPD** has underproduced compared with similar instruments at ISIS and SNS. This is a major issue for KEK and J-PARC, in that this type of instrument is generally the most productive of all instruments at spallation sources, with a world standard of ~50 papers per year being the norm. There are similar issues with iMATERIA, and the initial indications are that SPICA is doing no better. If KENS (and/or J-PARC) could diagnose and resolve these problems, it would make the whole facility look much more competitive.

We have not performed any citation analysis, but would make the following observation regarding the quality of the publications in the last three years (2017-2020):

HRC has a healthy mix of publishing user institutions, including 4 Japanese universities, some in-house research and two overseas labs (in China and Switzerland). There has been one *Phys. Rev. Letter*, one in each of *Scientific Reports* and *Science Advances*, as well as three in *Phys. Rev. B*. There was also a *Nature Communications* article in 2016.

NOVA has a very broad user base, with refereed articles from 10 different Japanese universities (the most important collaborations being with Tokyo Institute of Technology, Tokyo University of Science, Yamagata University and Kyoto University), 2 Japanese government labs (AIST and NIMS), one Japanese company (DENSO), and 3 papers from China, as well as 4 papers from KENS, JAEA and J-PARC. There have been 3 articles in *Journal of the American Chemical Society*, 3 in *Nature*-family journals, and one each in *Proceedings of the National Academy of Science (USA)*, *Scientific Reports* and *Adv. Mater*.

SOFIA has a very broad user base with refereed articles from 9 different Japanese universities (the most important collaborations being with Kyushu University and University of Tokyo), 3 Japanese government labs (AIST, RIKEN and the National Defence Academy), two Japanese companies (Toyota[3x] and Nitto Denko), and papers from each of the USA, Taiwan and Australia, as well as 2 papers from KENS and J-PARC. There have been 5 papers in *Langmuir* and 4 in *Macromolecules*.

SHRPD has a reasonable mix of publishing user institutions, including 7 Japanese universities (the most important of which is Tokyo Institute of Technology), and institutions in Korea, Germany and Thailand. A much larger proportion of the papers (33%) are internally driven by KENS (and J-PARC), than on the other instruments. While this speaks well for the KENS staff, it would appear that SHRPD is insufficiently engaged with the broader Japanese research community, and/or that they are not analysing and publishing their results. There have been 2 papers in *Journal of the American Chemical Society,* one each in *Nature Communications*, *Scientific Reports* and *Adv. Mater*., as well as five in *Physical Review*.

It is early days on **SPICA** but, so far, the instrument seems to have been exploited almost exclusively by Kyoto University and Tokyo Institute of Technology. The user base will have to broaden out significantly, as the user program grows, to involve more universities, other government labs and commercial companies. There has been one article in the *Journal of the American Chemical Society*, and one in *Phys. Rev. B*.

- **Evaluation of research outputs**

Aside from science done on the KENS instruments, KEK staff have reported on their research done using other neutron, synchrotron, and μSR instruments. Seven other non-KEK instruments feature on KENS publications, as well as the KEK μSR facilities at J-PARC. Three synchrotrons feature on KENS papers: the Photon Factory, SPRing-8 and the Taiwan Light Source, in that order, and KENS papers feature data taken on 5 different overseas neutron sources. There are also papers from the TRIUMF accelerator in Vancouver and using optical microscopy and mass spectrometry. This is all very healthy.

The number of postdoctoral fellows (almost 2 per beamline; or one per scientific staff member) and graduate students (>1 per beamline; almost one per scientific staff member) is quite healthy by international standards.

We note that KENS staff won the 2017 JSNS Technology Prize, for the implementation of Neutron Brillouin Scattering on HRC.

Notable recent work includes that on a new class of layered perovskites with high oxygen conductivity (2020 in *Nature Communications;* SHRPD), 9-fold hydride formation (2017 in *Scientific Reports*; NOVA), Ionic conduction via orientational disorder (2020 in *Applied Physics Letter*s, NOVA), Observation of the Higgs mode in $CsFeCl_3$ (2018 & 2019, in *Phys. Rev. B* and *Science Advances*; HRC), and new curved mirrors for reflectometry and spin-echo,

- **Evaluation of Funding situation**

We do not believe that KENS (or the MLF, for that matter) can be fully research competitive with ISIS, SNS and the leading research reactors, unless it is staffed at the international standard for neutron sources that run 200+ days per year.

The difference between the requested budget and actually funded budget is extremely high. Therefore it is clear to us that it has been very difficult to do as planned or aimed for, resulting in the extended instrument improvements and shortage of staff members.

- **Is KENS moving in the right direction? Are the future development items adequate?**

The future research directions and plans to understand the cross correlations in materials by precise neutron scattering measurements, which are dealing with important issues in each field, are well laid out. These efforts are expected to help to understand the fundamental interactions in materials and design materials of new emergent functional properties.

The continuing instrument improvement plans are adequate and well laid out, which is very good thing to do. However, it is concerned that the limited budget may have extended the period of instrument improvement, possibly interrupting stable use of instruments by users. Sufficient budget support for the instrument improvement is highly recommended so that the instruments can be operational with full capacity in a short period of time.

- **Evaluation of KENS and MLF Leadership – Is MLF a core academic research hub?**

  The leadership of KENS and MLF in the field of neutron science is very highly regarded. The MLF receives ca. 650 general beamtime proposals in 2020A from Japanese universities (43%), foreign institutes (31%), Japanese companies (9%) and others. The high proportion of proposals from foreign countries clearly demonstrates the very high international reputation and leadership of KENS and MLF.

  The instruments at KENS and MLF provide world top level measurement capability. The experiments performed at KENS and MLF by Japanese and international scientists and engineers cover a broad spectrum of academic disciplines including physics, chemistry, biology, soft matter, and materials science, resulting in publications in high profile journals such as *Nature Materials, Nature Physics, Physical Review Letters, Advanced Materials, The Journal of American Chemical Society* and so on. There is no doubt that the KENS and MLF have been an excellent core academic research hub for Japanese and international communities.

  We believe that the international leadership of KENS and MLF, and their roles as a core academic research hub will be significantly further strengthened if the budget and staff members are properly allocated at the international standard.