SIKA: Opportunities for Low-Energy Excitations Using Neutrons

The triple-axis spectrometer has been used by neutron scatters to study many areas of condensed matter physics for decades. A triple-axis spectrometer has the capability to investigate physical phenomena with high energy and momentum resolution with using cold neutrons. Currently time-of-flight spectrometry is advanced at spallation neutron sources, while the cold triple-axis spectrometer still has advantages of scanning S(*Q, ω*) space at each reciprocal point, measuring critical scattering, and availability of a number of sample environments.

Basic Components

The layout of a typical triple axis spectrometer is shown in **Fig.1**. **Table 1** shows the basic components of the cold triple axis spectrometer SIKA. One of the advantages of SIKA is a wide dance floor 55 m^2 allowing us to choose incident energies Ei = 2.6–25 meV. The neutron flux at the sample position is measured to be 1×10^8 n/cm^2s at λ = 2.1 Å. The analyzer drum hosts a ^{3}He Single Detector for two-axis mode (diffraction detector, DD), a ^{3}He Single Detector for triple-axis mode (single detector, SD), and a Position Sensitive Detector (PSD). The collimators are available for requirement of users as shown in **Table 1**. The accessible ranges of momentum and energy transfer on SIKA with these components are shown in **Fig.2**. Energy resolutions estimated by Vanadium are also shown in **Table 2**. Both PG filter (E_i > 5 meV) and Be filter (E_i < 5 meV) are available on SIKA. Our cold triple axis spectrometer SIKA has very big advantage of studying condensed matter physic below 5 meV with high energy resolution such as below dE < 0.1 meV compared to typical thermal triple axis spectrometers.

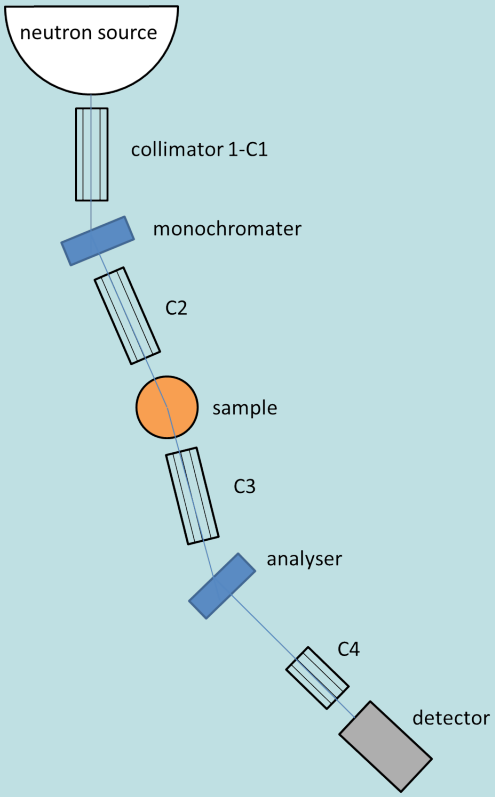


Fig.1: Layout of a typical triple axis spectrometer.

Sample Environment

The list of sample environment available on SIKA is provided in **Table 3**. The demands for dilution insert

Table 1: Components available on SIKA

Angular range
28.4 degrees < $2\theta_M$ < 120 degrees
-100 degrees < $2\theta_S$ < 100 degrees
-90 degrees < $2\theta_A$ < 90 degrees
Monochromator
Pyrolytic graphite (002)
Flat, vertical, horizontal, and double focusing
Ei range: 2.43–30 meV
Filters
PG filters (2 cm, 3 cm, 2 + 3 cm = 5 cm)
Cooled Be filter
Flux at sample position
1×10^8 n/cm^2s (at λ = 2.1 Å)
Detectors
^{3}He Single Detector for diffraction and inelastic
1D position sensitive detector (PSD)
Collimators
Pre-monochromator (C1): Open, 20′, 40′, 60′
Post-monochromator (C2): Open, 20′, 40′, 60′
Pre-Analyzer (C3): Open, 20′, 40′, 60′
Pre-single detector (C4s): Open, 20′, 40′, 60′
Pre-PSD (C4r): Radial collimators

Table 2: Energy resolution (meV) with vertical focusing mode with conditions estimated with Vanadium

Collimations - E_i	14.87	8.07	5.11	2.6
20′-20′-20′-20′	0.448	0.160	0.083	0.024
40′-40′-40-Open	0.778	0.315	0.153	0.035
60′-60′-60′-Open	0.769	0.323	0.146	0.041

(~50 mK) and magnet (vertical up to 12 T) are high.

Software

The SIKA team has developed the software SIKA-SPICE based on the Spectrometer and Instrument Control Environment SPICE.[1] SIKA-SPICE is built on client server architecture so you can control SIKA with any one of three computers located at dance floor, in the reactor beam hall, or in the SIKA cabin.

SIKA-client

The SIKA client was built to control the instrument and has two displays. One views the current status on SIKA whereby monitor, axes for triple-axis, temperatures, and axes other than triple-axis are easily checked whilst controlling SIKA. The second display is for commands to control instrument and sample environment. The command screen will also be used to edit scans, macros, sample information (single crystal, powder, lattice parameters, compositions, and so on), and the UB-matrix for the experiment. The software and hardware limits for the instrument are also displayed here (**Fig. 3**).

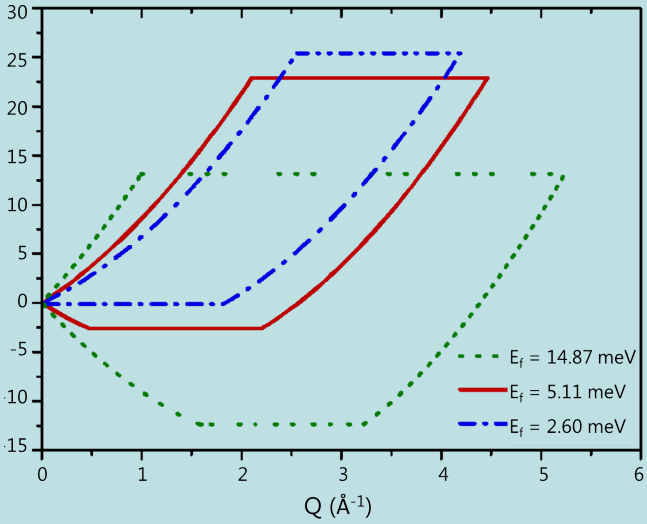


Fig.2: Accessible ranges of the momentum and energy transfer of SIKA at various final energies.

SIKA Analysis

SIKA analysis software (**Fig. 4**) has been developed. It is still improving its functionalities, due to comments from active and internal users during commissioning and the user program. The software allows us to plot and normalize data. Users can also compare, manipulate, and export scans as text data. 2D plots are useful when you are observing dispersion relations in energy and momentum space.

Experimental Capability

The subjects proposed for SIKA are mainly highly-frustrated magnetism, superconductivity, magnetism (general, 5d transition-metal, low-dimensional), multiferroics, soft matter thin film, *etc*.

We will now present you example of scientific capability of SIKA. **Figure 5** shows the magnon dispersion of MnF_2 has been measured on SIKA. The magnon dispersion of MnF_2 has been measured on SIKA. MnF_2 is a classic material for studying spin waves in an antiferromagnet described also in textbooks.[2] The experiment conditions were E_f-fixed with 8.07 meV, collimations of 60′(C1)-60′(C2)-60′(C3)-60′(C4) (for details, see **Table 1**). We needed only one minute for each point since Mn has a large magnetic moment; $S = 5/2$. The determined exchange parameters are $J_1 = 0.031$, $J_2 = 0.153$, and $D = 0.143$ meV by fitting the data based on equation (1).

Table 3: Sample environments normally requested on SIKA.

	Environment	Sample	Type	Other
CF-4	4–300 K	Bottom loading	Closed cycle	
OC-1	0.5–80 K(1) 1.5–300 K	Top loading	ILL- Orange	(1)
CF-7 or CF-8	4–750 K	Top loading	Closed cycle	
CF-12	1.5–800 K	Top loading	Closed cycle	(2)
AVM-1	50 mK–80 K 1.5–300 K 0–12 T	Top loading	Vertical magnet (Oxford)	(3)

(1) OC-1 can be used with the 3He one-shot fridge insert to reach temperatures of 0.5 K to 80 K.

(2) CF-12, if user wants to go above 300 K, sample stick for high temperature should be requested.

(3) In conjunction with the Kelvinox dilution insert DL-1, a base temperature 50 mK can be achieved.

* The above information is available at http://www.ansto.gov.au/ResearchHub/Bragg/Facilities/SampleEnvironments.

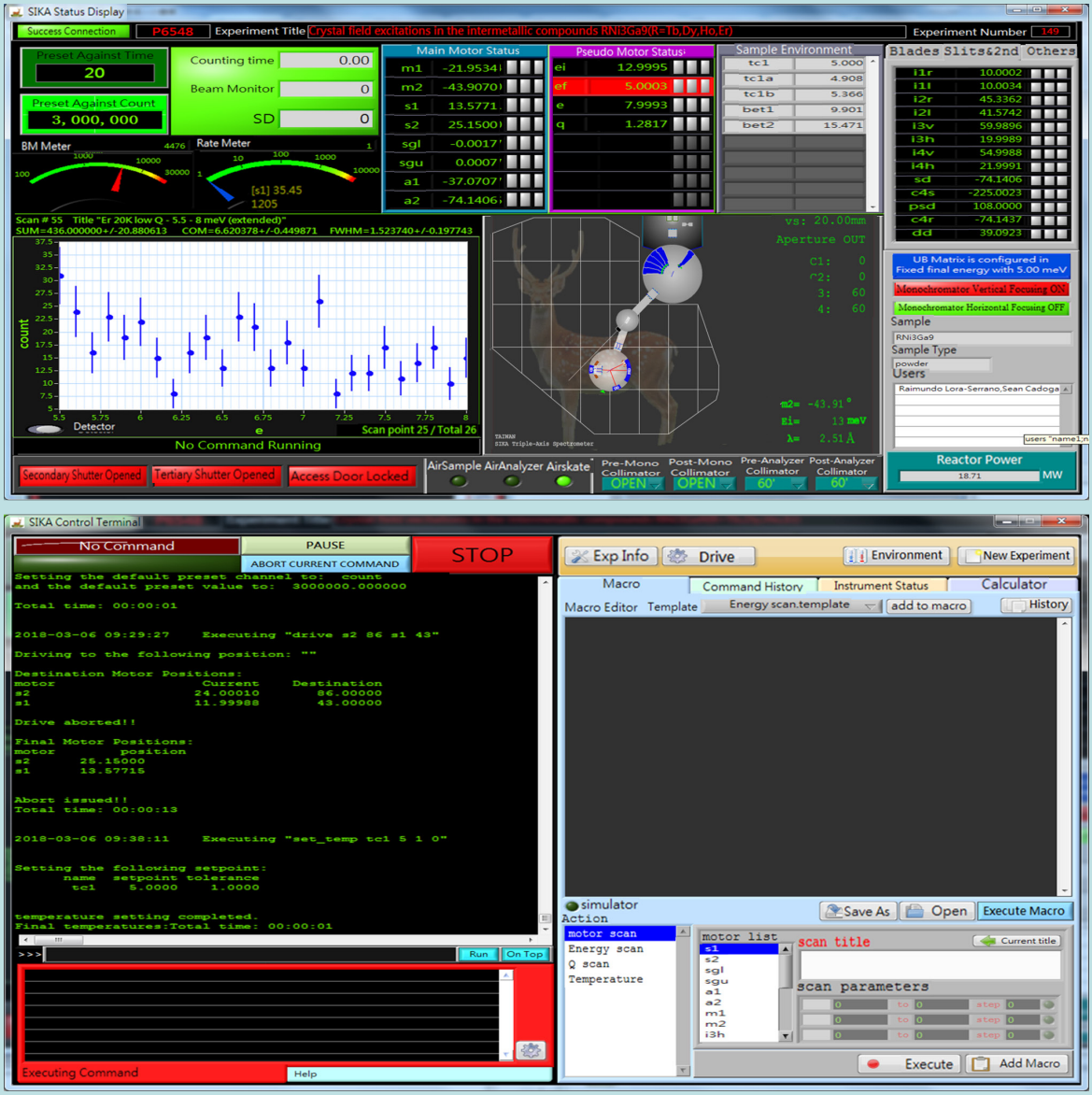


Fig.3: SIKA client.

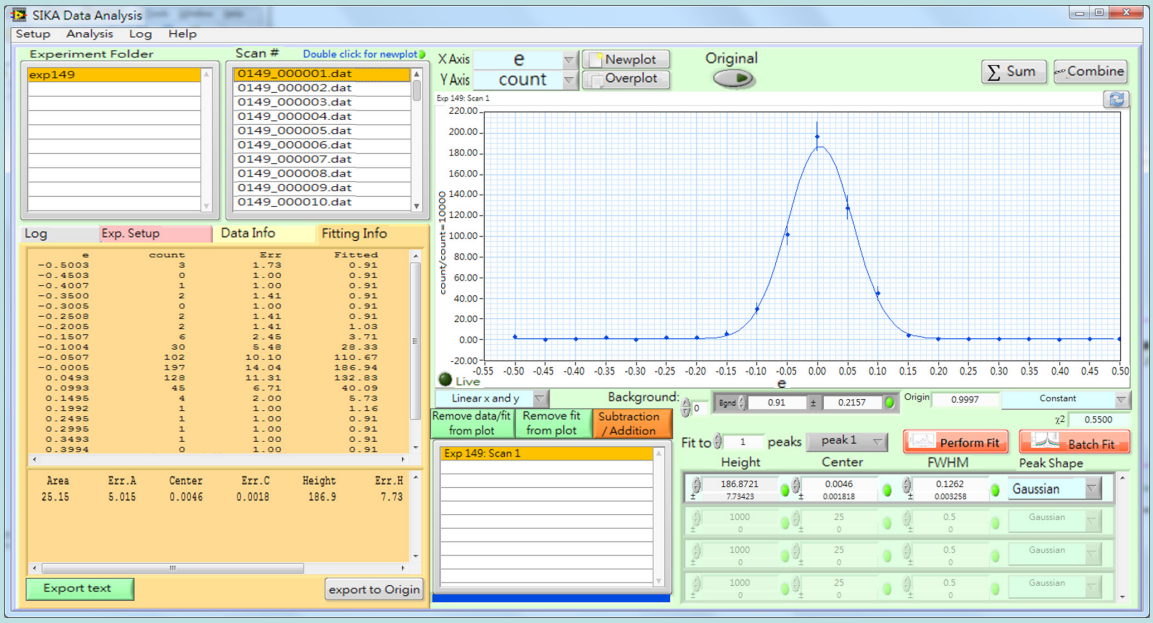


Fig.4: SIKA analysis software.

Equation (1) $\hbar\omega_q = 16 \cdot s \cdot j_2 \{(1+\zeta)^2+\gamma^2\}^{1/2}$

Literature says $J_1 = 0.032$, $J_2 = 0.155$, and $D = 0.11$ meV.[3]

With $s = 5/2$, z_1 (nearest) = 2, and z_2 (next nearest) = 8 and when we are scanning along q_c.

Equation (2) $\zeta = [D+8 \cdot s \cdot j_1 \sin^2\left(\frac{1}{2} \cdot q_z \cdot c\right)]/16 \cdot s \cdot j_2$

Equation (3) $\gamma = \cos^2\left(\frac{1}{2} \cdot q_z \cdot c\right)$

Future Progress

We are working on several improvements to enhance SIKA capabilities. One is taking advantage of a multiplexing analyzer, co-aligning 13 HOPG analyzer blades being 20 mm wide and 150 mm tall sitting on detector drum. With this multi-blade analyzer system, SIKA will have the capability of a RITA-type analyzer instrument.[5] A polarized ^{3}He neutron spin filter is under commissioning and will be available on SIKA to perform polarized neutron scattering experiments and polarization analysis. We are hoping for more new Taiwanese users in 2018. (Reported by Shinichiro Yano)

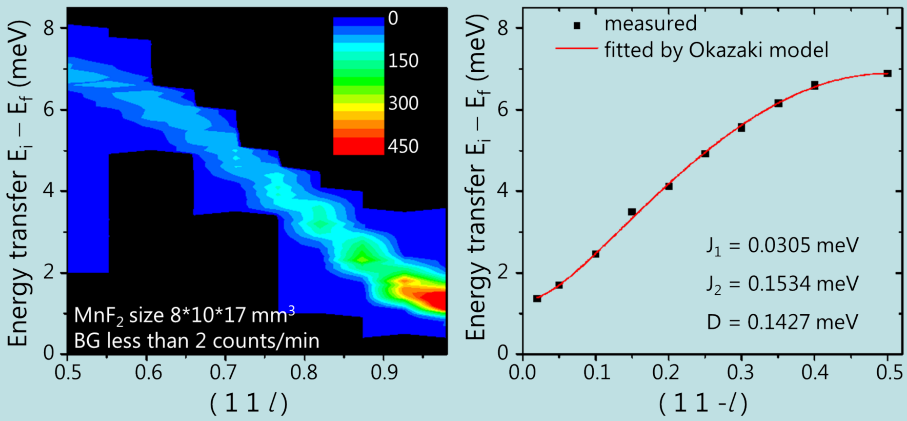
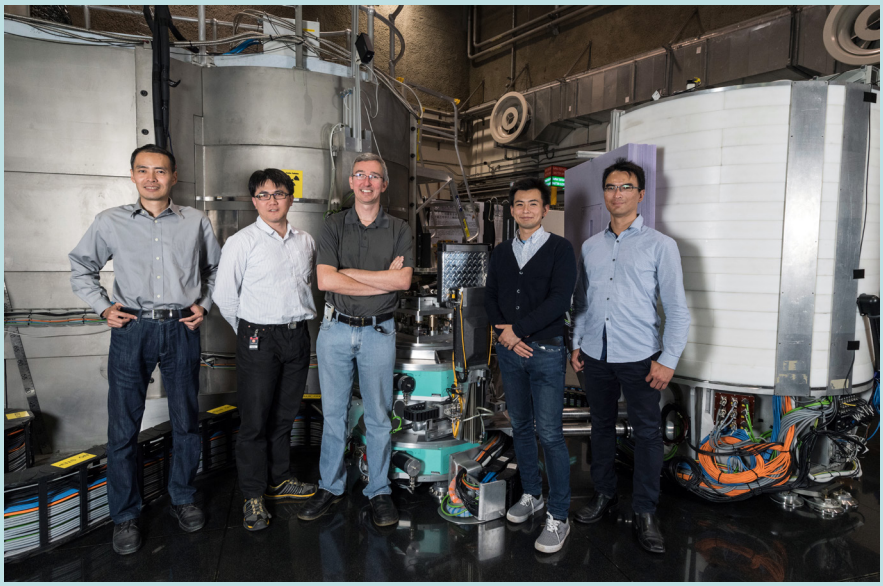


Fig.5: Magnon dispersion of MnF2 single crystal measured with SIKA.



SIKA and Taiwan team.

References

1. M. D. Lumsden, J. L. Robertson, and M. Yethiraj, Physica B, **385-386**, 1336 (2006).
2. G. Shirane, S. M. Shapiro, and J. M.Tranquada, Neutron Scattering with a Triple-Axis Spectrometer. Cambridge University Press (2003).
3. A. Okazaki, K. C. Thurberfield, and R. W. H. Srevenson, Phys. Lett., **8**, 9 (1964).
4. J. W. Lynn, Y. Chen, S. Chang, Y. Zhao, S. Chi, W. Ratcliff II, B. G. Ueland, and R. W. Erwin, J. Res. Natl. Inst. Stand. Technol., **117**, 61 (2012).
5. J. W. Lynn, Y. Chen, S. Chang, Y. Zhao, S. Chi, W. Ratcliff, B. G. Ueland, and R. W. Erwin, J. Res. NIST **117**, 61 (2012).