



中国原子能科学研究院
CHINA INSTITUTE OF ATOMIC ENERGY

Development of Neutron Optic devices at CARR

Zijun Wang

China Institute of Atomic Energy (CIAE)

2024.10.11, Yekaterinberg

CONTENTS

01 China Advanced Research Reactor (CARR)

02 Neutron Optic Devices

◆ Neutron collimators

◆ Neutron monochromators

03 Summary

01

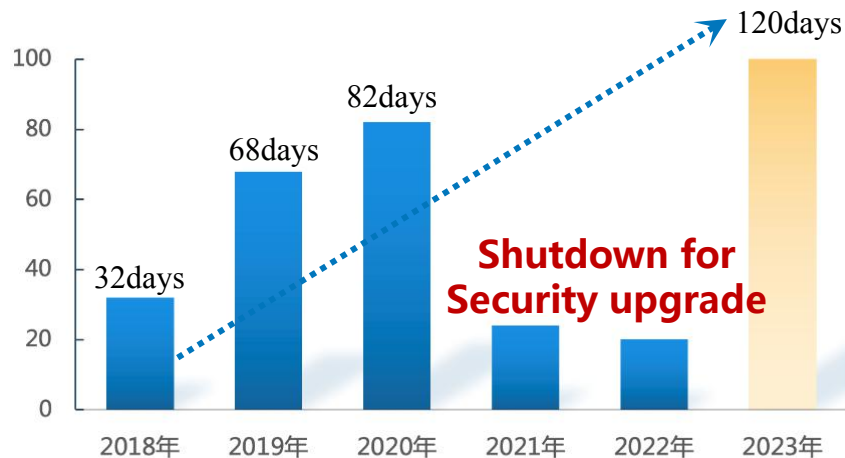
China Advanced Research Reactor

- 60 MW, reach full power in 2012
- Max flux: 1×10^{15} n/s/cm²
- 19.75 wt% U²³⁵
- **Horizontal tube: 9**
- **Vertical tube: 25**



Multipurpose:

- **Neutron scattering & imaging**
- **Neutron activation analysis**
- **Radio-isotope production**
- **Irradiation test of materials**
- **Nuclear data**



Reactor Hall



In operation : 9
Under construction : 1

Guide Hall



In operation : 6
Under construction : 2

02

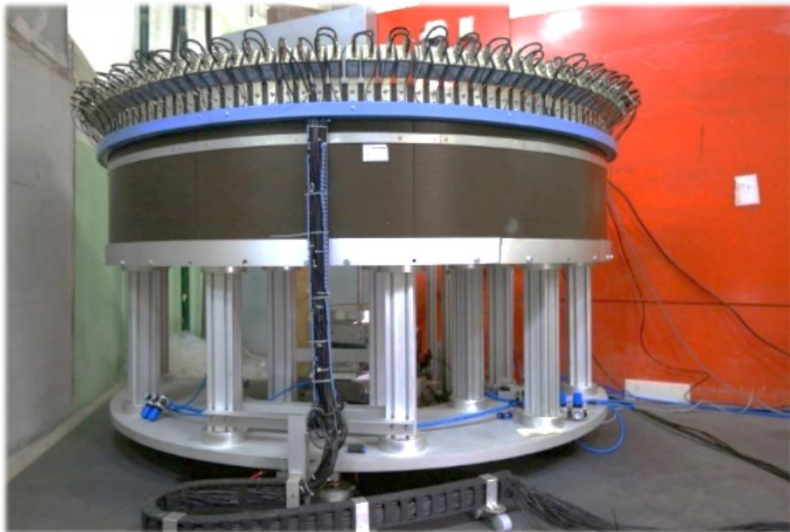
Neutron Optic Devices

2-1 Soller collimator

2-2 Radial collimator

◆ 2-1 Soller collimator

Motivation

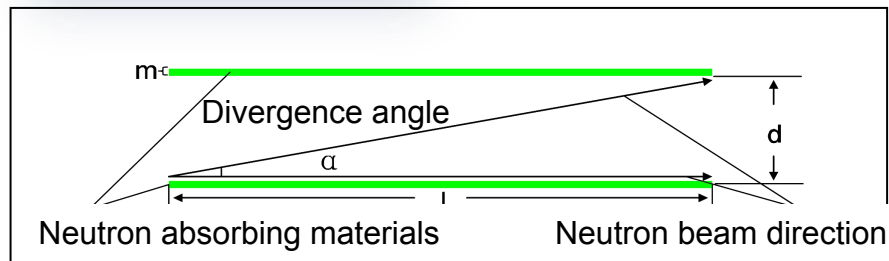
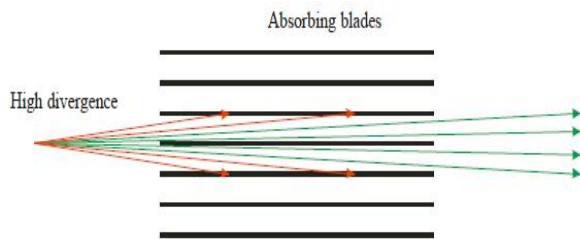


High Resolution Powder Diffractometer @CARR

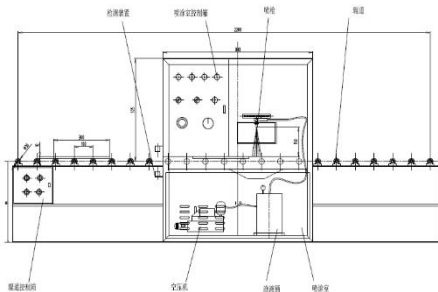
- ◆ Improve the resolution
- ◆ Enhance the signal to noise ratio

◆ 2-1 Soller collimator

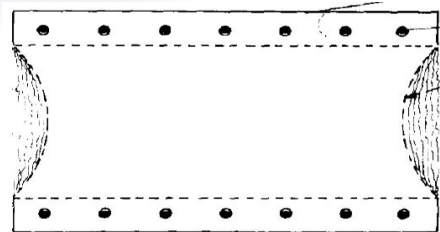
Conceptual design



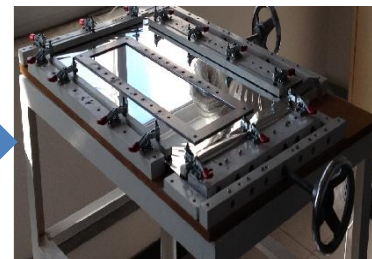
Mechanical design



Spraying process



Cutting process

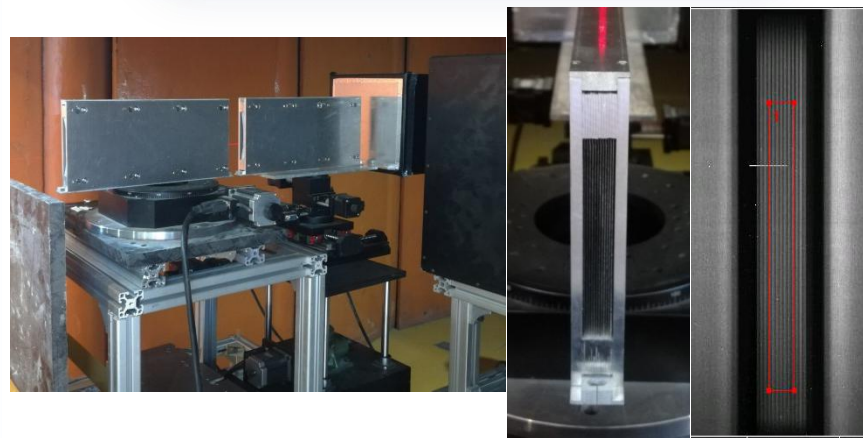


◆ 2-1 Soller collimator

Integral assembly



Transmission efficiency experiment



The divergence angle reaches **10'**, the **neutron transmission efficiency** reaches **95%**

◆ 2-2 Radial collimator

Motivation

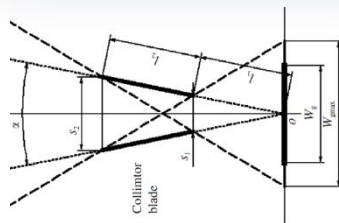
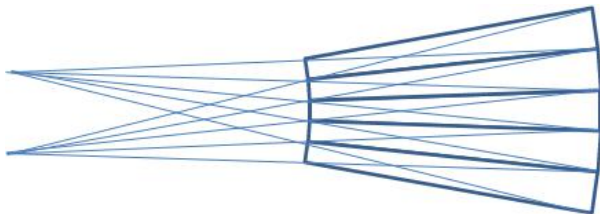


Residual Stress Diffractometer @CARR

- ◆ Higher resolution
- ◆ Set gauge volume at long distance

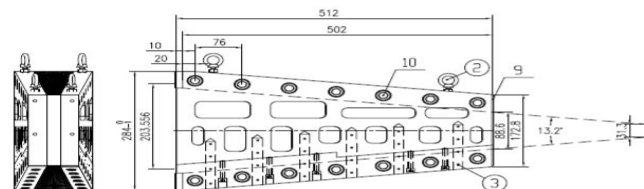
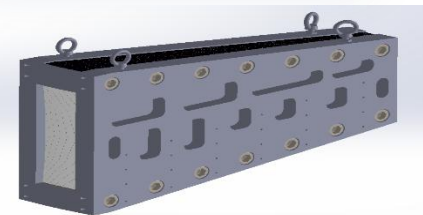
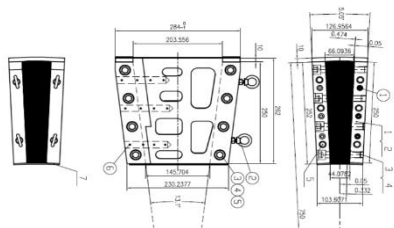
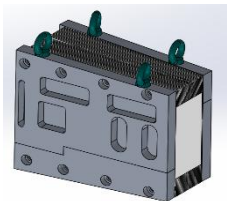
◆ 2-2 Radial collimator

Conceptual design



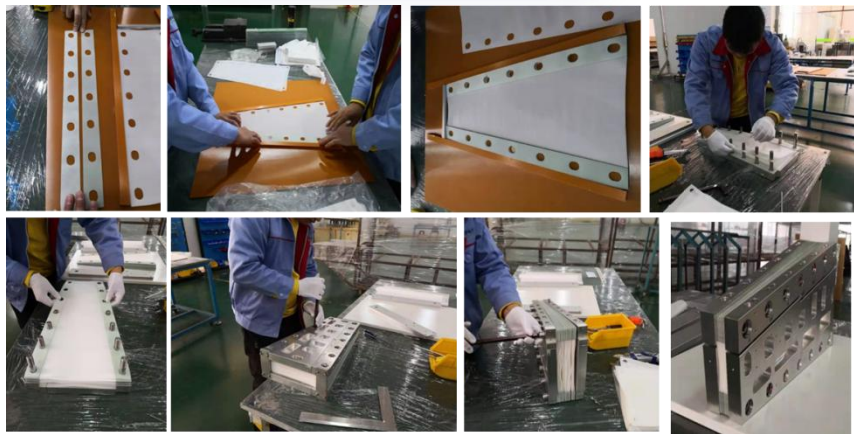
RC size(mm)	S1 (mm)	L1 (mm)	L2 (mm)	S2 (mm)	Number of Channels to get 5°	Transmission Ratio	
						t=0.05mm	t=0.08mm
1	0.621	200	550	2.33	28	92.0%	87.1%
1	0.508	300	450	1.27	51	90.2%	84.3%
1	0.395	400	350	0.74	88	87.4%	79.8%
1	0.282	500	250	0.42	154	82.3%	71.7%

Mechanical design



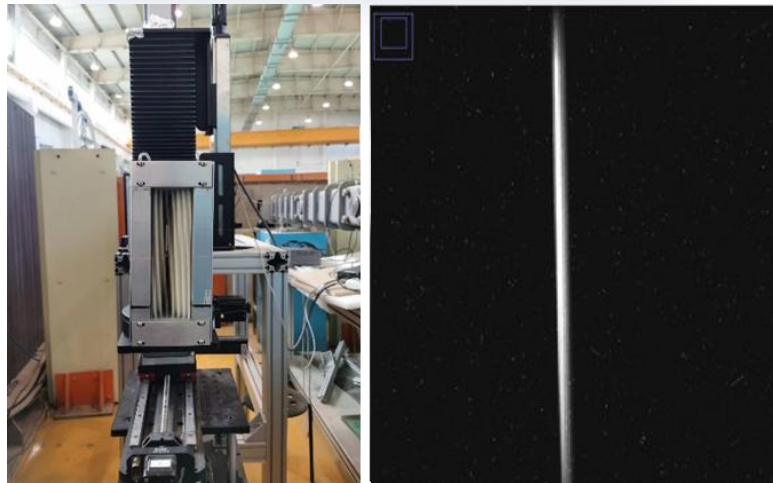
◆ 2-2 Radial collimator

Integral assembly



Cutting、 positioning、 assembling

Transmission efficiency experiment



When the **gauge size** is set **1mm**, the **neutron transmission efficiency** reaches **83%**

02

Neutron Optic Devices

2-3 Focusing (Ge/Si) monochromator

2-4 Double crystal monochromator

◆ 2-3 Germanium hot pressing process and equipment

developed equipment



Main parameters

Heating Power	9000 W
Max Temperature	950 °C
Heating chamber size	Φ290×400 mm
Temperature control accuracy	±1 °C
Thermostatic zone size	Φ120×80 mm
Thermostatic temperature difference	±5 °C
Temperature range	80—950 °C
Vacuum	≤3 Pa
Device dimensions	4030×990×2643 mm

◆ 2-3 Germanium hot pressing process and equipment

Product: Ge(115)

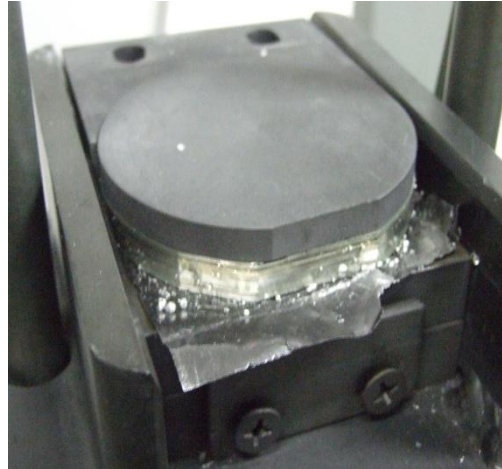
Ge Crystal Cylinder



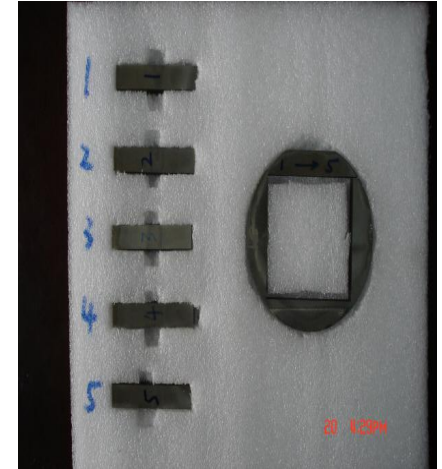
Hot pressing



Welding

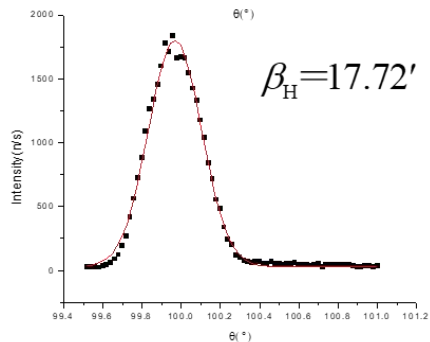
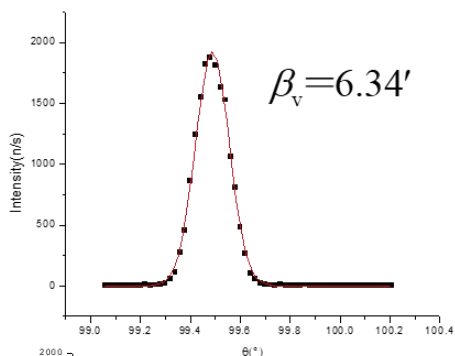


Cutting



The general process of the Germanium crystal hot pressing technology

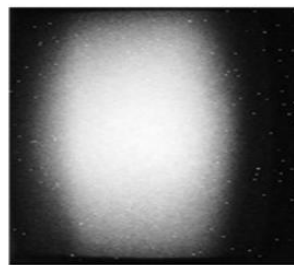
◆ 2-3 Germanium hot pressing process and equipment



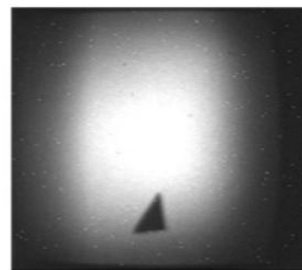
Horizontal and vertical Mosaic

Ge(115) crystal

Flat-plate type



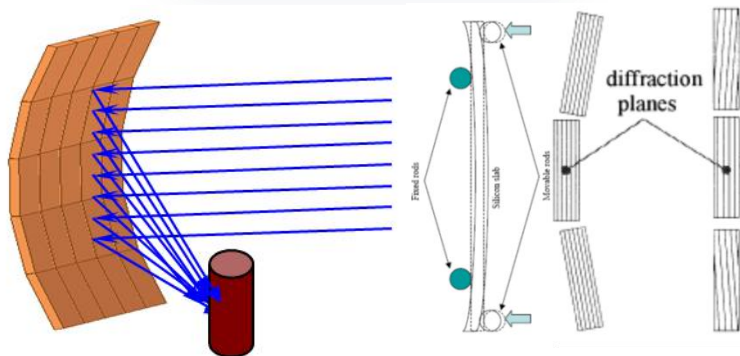
vertical focusing type



The neutron intensity gain reaches about 3 times

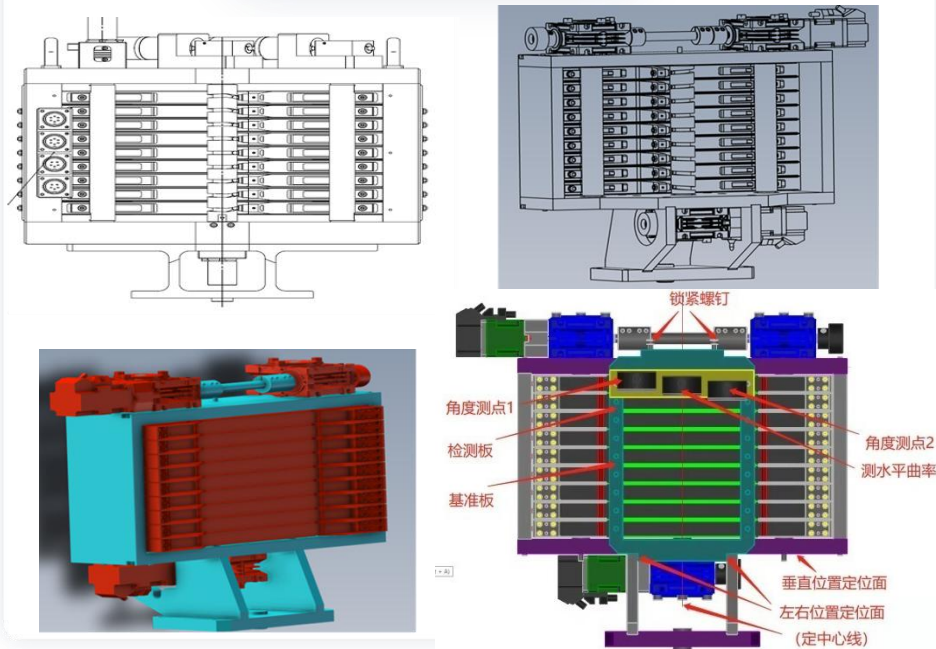
◆ 2-3 Double focusing silicon monochromator

Conceptual design



Silicon monochromator size	170cm*270cm*12mm
Crystal plane	Si(400)
Wavelength	1.478Å
Radius of horizontal curvature	$3m < R_h < 10m$
Vertical radius of curvature	$1.5m < R_v < 8m$

Mechanical design

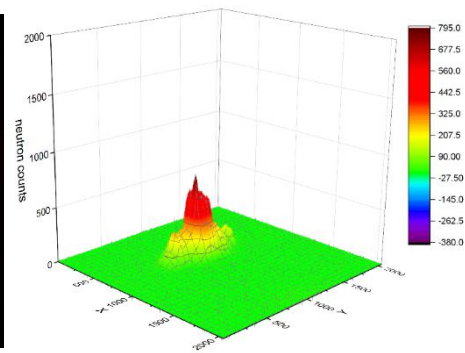
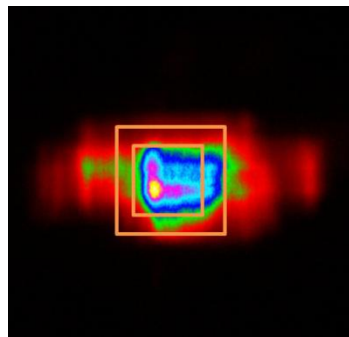


◆ 2-3 Double focusing silicon monochromator

Integral assembly



Neutron experiment



The minimum focusing radius of 2.6m and 1.3m; The **neutron intensity gain 20 times**

◆ 2-4 Double crystal pyrolytic graphite

Motivation



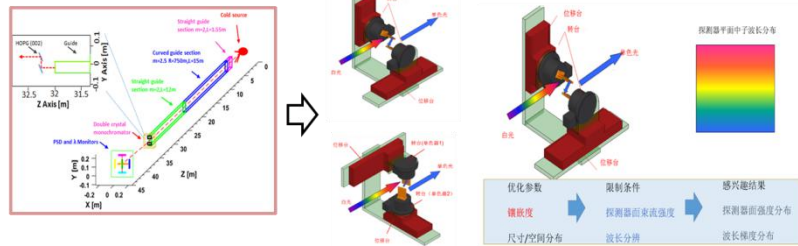
Neutron Imaging @CARR

- ◆ Selected energy
- ◆ High wavelength resolution

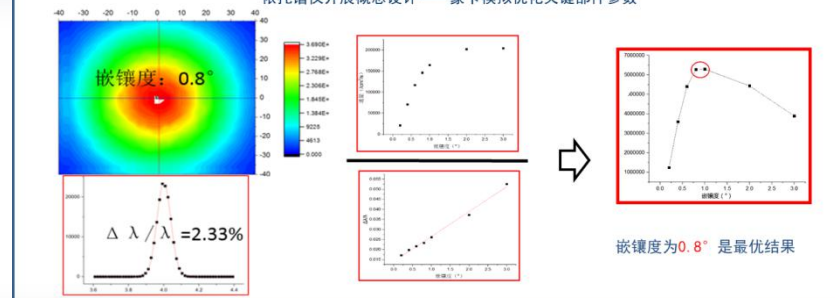
◆ 2-4 Double crystal graphite

Conceptual design

依托谱仪开展概念设计——蒙特卡模拟优化关键部件参数

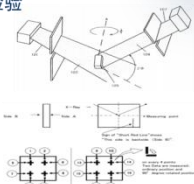
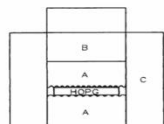


依托谱仪开展概念设计——蒙特卡模拟优化关键部件参数



Mechanical design

大尺寸石墨单晶片制备与检验

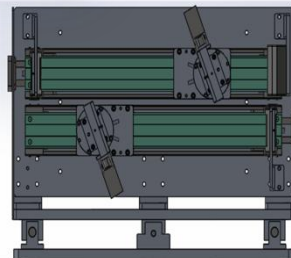


(6) Evaluation data

Side A				Side B			
No.	F/F0	Re	F/F0	No.	F/F0	Re	F/F0
1	0.009	5	0.021	9	0.009	13	0.017
2	0.012	6	0.019	10	0.004	14	0.003
3	0.014	7	0.020	11	0.010	15	0.020
4	0.015	8	0.041	12	0.010	16	0.013

双单晶石墨片晶面平行及同步技术

双转台主要部件名称及技术参数



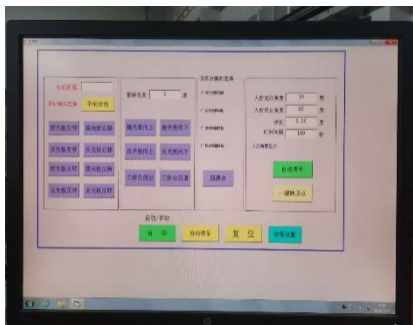
1. 单轴驱动器 (模组): 重复定位精度 $\pm 0.02\text{mm}$,
2. 上下中心距离: 90mm;
3. 转动角度: $10^\circ \sim 65^\circ$;
4. 转动精度: $\pm 0.001^\circ$;
5. 热解石墨片: $70 \times 70 \times 2\text{mm}$
6. 前后限束: $50 \times 50\text{mm}$;
7. Beamstop: $60 \times 60\text{mm}$;
8. 石墨片加垂直于中子束方向的倾角调整装置, 调节平行;

◆ 2-4 Double crystal graphite

Integral assembly

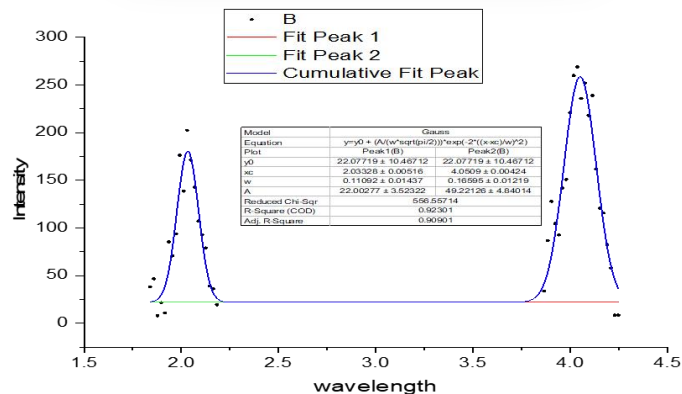


monochromator



Control system

Neutron experiment



The **wavelength resolution** can achieve **2.6%(@4Å)**

03

Summary

3. Summary

Neutron collimator

- ◆ Neutron Soller collimator
- ◆ Neutron Radial collimator

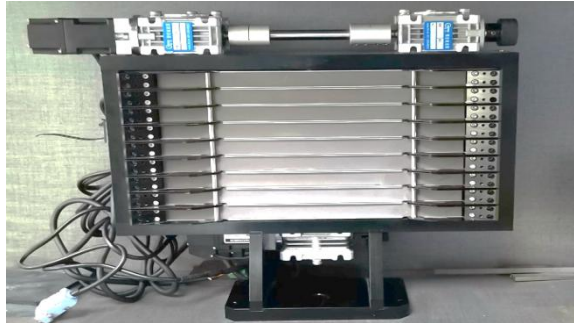
Contact:
liyuqing0526@hotmail.com

Neutron monochromator

- ◆ Double focusing (Si)
- ◆ Vertical focusing (Ge)
- ◆ Double crystal graphite

Contact:
wzj2345@163.com

Contact:
hlf1212@sina.com



We hope technical cooperation in upgrading and developing neutron optics !



中核集团
CNNC

中国原子能科学研究院

CHINA INSTITUTE OF ATOMIC ENERGY

Thanks for your attention !

