Seminar R & D 2014
Agensi Nuklear Malaysia

Simulations of Neutron Beam Optic For Neutron Radiography Collimator Using Ray Tracing Methodology

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Presentation Outline

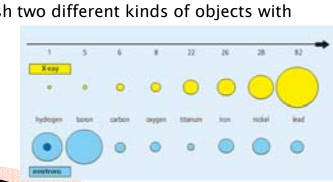
- Introduction
- Objective
- RTP Neutron Radiography
- McStas Code development
- Simulations
- Conclusion

Introduction

- Neutron Beam Optic
  - Neutron optics – Theory and applications of the wave behaviour of neutrons. It involves studying the interactions of matter with a beam of free neutrons.
  - 2 major sources of free neutrons for neutron-beam production: (1) the neutrons emitted in fission reactions at nuclear reactors (2) the neutrons released in particle-accelerator collisions of proton beams with targets of heavy atoms.
  - When a neutron beam is directed onto a sample of matter, the neutrons can be reflected, scattered, or diffracted, depending on the composition and structure of the sample and on the properties of the neutron beam.

Introduction (cont.)

- Neutron Radiography
  - One of neutron beam facilities
  - Neutron and x-ray images complementary to one another
  - X-ray attenuation increases with atomic mass
  - Neutron attenuation is random with respect to atomic mass
  - Can obviously distinguish two different kinds of objects with close atomic number



Introduction (cont.)

- McStas
  - Monte-Carlo Simulation of Triple Axis Spectrometers
  - Free open-source software package based on C language developed by K. Lefmann and K. Nielsen that works on all system (Linux,Win, MacOSX, iPhone…)- started 1998
  - Funded by EU: Peter Willendrup, Emmanuel Farhi & others (Risø & ILL)
  - Tool for carrying out ray-tracing simulations for neutron instruments.

Introduction (cont.)

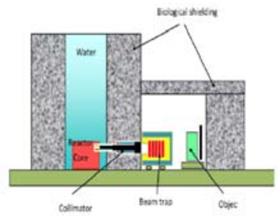
- McStas
  - Suitable for neutron scattering studies, e.g. SANS, diffraction, imaging. Propagates neutrons with Newton laws and handle low energy scattering (E < 100 meV)
  - Design new instruments, optimize existing instruments (flux/resolution), optimize usage of existing instruments for better experiments, compare virtual experiments with real ones, possibly during experiment
  - Can not handle high energy moderation
  - Not appropriate to estimate fast neutron background

Objective

Preliminary study:

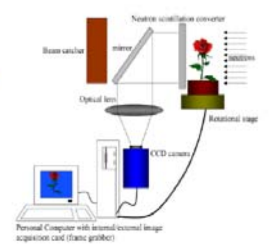
- To explore the implementation of ray-tracing technique using McStas software
- To develop the McStas code for RTP neutron radiography facility
- To simulate the performance of neutron collimation system developed for imaging system of TRIGA RTP reactor

RTP Neutron Radiography



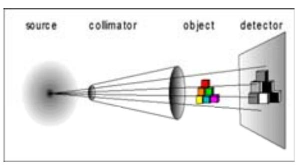
Side view of NUR facility

Schematic set up of digital neutron radiography



Source:
Khalid et al., 2010
IAEA TM 38728

McStas Code Development



Neutron Radiography System

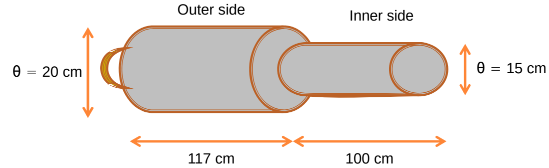
Source
- neutron source from the reactor core

Collimator
- guide the neutrons to the investigated object

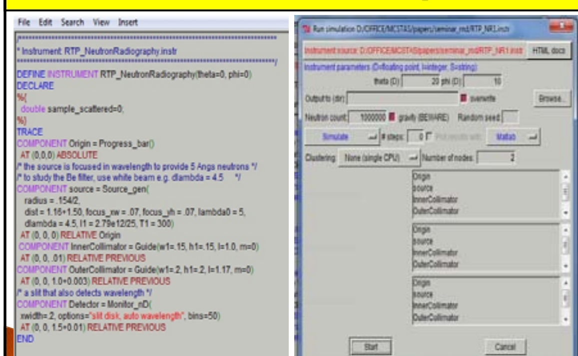
Detector
- plane integrating position-sensitive imaging devices containing material with a high neutron cross-section functioning as neutron converter and a recorder
- collecting the signal emitted by the converter during exposure, read out radiographic image

RTP Neutron Radiography

Collimator Geometry (RTP latest measurement)



McStas Code Development



```
/*******************************************************************
* Instrument: RTP_NeutronRadiography.instr
*******************************************************************/
DEFINE INSTRUMENT RTP_NeutronRadiography(theta=0, phi=0)
DECLARE
%{
 double sample_scattered=0;
%}
TRACE
COMPONENT Origin = Progress_bar()
 AT (0,0,0) ABSOLUTE
/* the source is focused in wavelength to provide 5 Angs neutrons */
/* to study the Be filter, use white beam e.g. dlambda = 4.5     */
COMPONENT source = Source_gen(
  radius = .154/2,
  dist = 1.16+1.50, focus_xw = .07, focus_yh = .07, lambda0 = 5,
  dlambda = 4.5, I1 = 2.79e12/25, T1 = 300)
 AT (0, 0, 0) RELATIVE Origin
COMPONENT InnerCollimator = Guide(w1=.15, h1=.15, l=1.0, m=0)
 AT (0, 0, .01) RELATIVE PREVIOUS
COMPONENT OuterCollimator = Guide(w1=.2, h1=.2, l=1.17, m=0)
 AT (0, 0, 1.0+0.003) RELATIVE PREVIOUS
/* a slit that also detects wavelength */
COMPONENT Detector = Monitor_nD(
 xwidth=.2, options="slit disk, auto wavelength", bins=50)
 AT (0, 0, 1.5+0.01) RELATIVE PREVIOUS
END
```

McStas Code Development

C- based programming for components (Course collimator ~ straight guide)

```
DEFINE COMPONENT Guide
DEFINITION PARAMETERS ()
SETTING PARAMETERS (string reflect=0, w1, h1, w2=0, h2=0, l, R0=0.9
OUTPUT PARAMETERS (pTable)
/* Neutron parameters: (x,y,z,vx,vy,vz,t,sx,sy,sz,p) */
SHARE
%{
%include "read_table-lib"
%include "ref-lib"
%}

DECLARE
%{
  t_Table pTable;
%}

INITIALIZE
%{
  if (mcgravitation) fprintf(stderr,"WARNING: Guide: %s: "
    "This component produces wrong results with gravitation !\n"
    "Use Guide_gravity.\n",
    NAME_CURRENT_COMP);

  if (!w2) w2=w1;
  if (!h2) h2=h1;
```

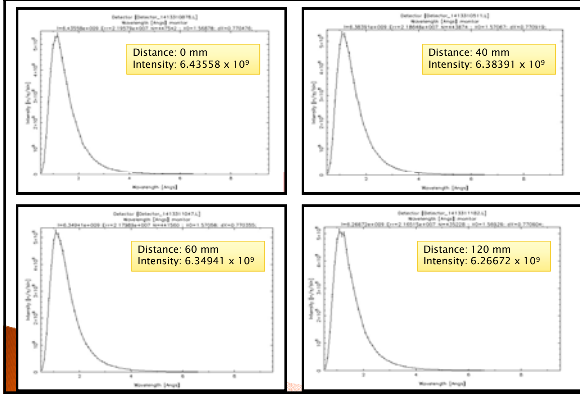
```
TRACE
%{
  double t1,t2;                                  /* Intersection times. */
  double av,ah,bv,bh,cv1,cv2,ch1,ch2,d;          /* Intermediate values */
  double weight;                                 /* Internal probability weight */
  double vdotn_v1,vdotn_v2,vdotn_h1,vdotn_h2;    /* Dot products. */
  int i;                                         /* Which mirror hit? */
  double q;                                      /* Q [1/AA] of reflection */
  double nlen2;                                  /* Vector lengths squared */

  /* ToDo: These could be precalculated. */
  double ww = .5*(w2 - w1), hh = .5*(h2 - h1);
  double whalf = .5*w1, hhalf = .5*h1;

  /* Propagate neutron to guide entrance. */
  PROP_Z0;
  /* Scatter here to ensure that fully transmitted neutrons will not be
     absorbed in a GROUP construction, e.g. all neutrons - even the
     later absorbed ones are scattered at the guide entry. */
  SCATTER;
  if(x <= -whalf || x >= whalf || y <= -hhalf || y >= hhalf)
    ABSORB;
  for(;;)
  {
    /* Compute the dot products of v and n for the four mirrors. */
    av = l*vx; bv = ww*vz;
    ah = l*vy; bh = hh*vz;
```

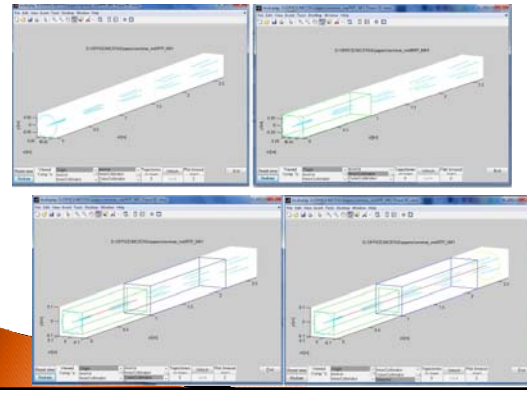
Simulations:

Intensity is higher as the distance between beam axis and collimator is closer



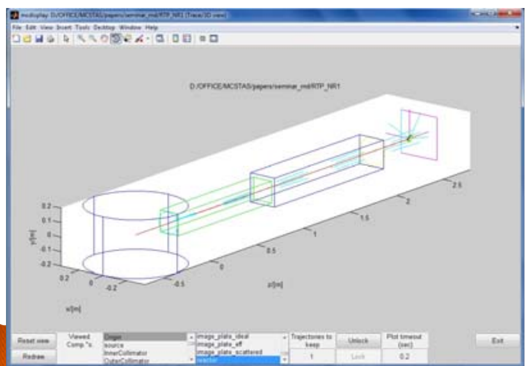
Simulations:

3D view of neutron path through out the basic instrument



Simulations:

3D view of neutron path through out the instrument with object , image plate and the reactor shape



Conclusions

- Exploratory research on McStas properties and applications
- McStas code for a simple RTP neutron radiography facility is developed based on the actual collimator measurement
- The performance of neutron collimation system developed for imaging system of TRIGA RTP reactor can be simulated based on the neutron intensity.
- McStas able to simulate the 3D- view of neutron trajectory and neutron radiography instrument and related components
- The code and simulations can be enhanced to solve more interesting / actual problem, in which more reliable analysis can be conducted

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THANK YOU