Sergey Stepanov

X-Ray Server As A Resource For Studies Using Grazing Incidence X-Ray Techniques

What is X-ray Server?

X-ray Server is a public project that I launched in **1997** with the goals to provide scientific community with a wider access to personal research results, establish scientific collaborations, and refine X-ray scattering models and scientific software.

The Server provides Web-based access to a number of programs implementing author's models in the field of X-ray diffraction and scattering. Thus, the project is a combination of physics and programming with physics being a lead and software being a tool.

The software operates directly on the Server available for use without downloading. At present seven programs are accessible that have been used more than **120,000** times by more that **5,500** colleagues worldwide.

Currently at: **http://sergey.gmca.aps.anl.gov**

Formerly at: **http://sergey.bio.aps.anl.gov**

Software available through X-ray Server

This site has been online since 1997 and has served **122,102** x-ray jobs

x_{0h} on the Web !!! x_{0h} search	***X0h*** interpolates dielectric susceptibilities x_0 and x_h for some crystals and other materials in wide range of x-ray wavelengths with the option to compare data from different databases. ***X0h-search*** is a tool to search for Bragg planes under various conditions.	**58,245 jobs**
GID_SL on the Web Dynamical x-ray diffraction from strained crystals, multilayers and superlattices at usual and grazing incidence angles	***GID_SL*** on the Web calculates x-ray diffraction curves of strained crystals and multilayers for any Bragg-case diffraction with scans around arbitrary axis. It replaces Takagi-Taupin equations for extremely asymmetric and grazing incidence diffraction.	**31,534 jobs**
TER_SL on the Web X-ray specular reflection from multilayers with rough interfaces at grazing incidence	***TER_SL*** on the Web calculates x-ray specular reflection and standing waves from multilayers with interface roughness and transition layers. It uses a new recursive algorithm converging faster than the recursions by Parratt.	**12,438 jobs**
TRDS_SL on the Web X-ray diffuse scattering at grazing incidence from surface and interface roughness	***TRDS_SL*** on the Web calculates x-ray diffuse scattering from interface roughness. It implements several different models of roughness and can simulate effects of skew roughness transfer, dependence of interface-interface roughness correlations on lateral size of roughness and x-ray scattering from atomic steps.	**9,811 jobs**
MAG_SL on the Web X-ray resonant specular reflection from magnetic multilayers	***MAG_SL*** on the Web calculates x-ray resonant specular reflection from magnetic multilayers with interface roughness and transition layers. It can also supply wavefields for calculations of diffuse scattering from magnetic roughness.	**8,749 jobs**
BRL on the Web X-ray multiple Bragg/Laue diffraction	***BRL*** on the Web applies a novel algorithm to calculate multiple Bragg diffraction of x-rays including the cases of x-ray waves grazing along the crystal surface and Bragg angles at 90 degr.	**1,325 jobs**

Based on ~17 research papers

Background algorithm

X0h calculates material susceptibilities χ_0 and χ_h for x-ray wavelength range by interpolating data tabulated in the International Tables for X-ray Crystallography and several other tables.

The highlight of ***X0h*** is the way it interpolates the dispersion corrections *df'* and *df"* [1]. The dispersion corrections are calculated with the formulae given by Don Cromer [Acta Crystallogr. vol.18 (1965) p.17-23]:

$$df' = \sum_{k=1}^{N_S} g_k P(X_k, N_k)$$

$$df'' = 0.5\pi \sum_{k=1}^{N_S} g_k (N_k - 1) / X_k^{N_k - 1}$$

First, ***X0h*** applies the above equations to known tabulated dispersion corrections and evaluates oscillator strengths g_k. Then, it uses calculated g_k to find the dispersion corrections of interest.

Once the χ_0 and χ_h are found, ***X0h*** can fulfill a lot of useful service tasks like evaluating the HWFM of Bragg peaks, searching for Bragg reflections that satisfy certain conditions, and *etc*.

Originally developed for the studies of parametric X-ray radiation by relativistic electrons, now ***X0h*** is primarily used for synchrotron radiation and automatically called by all other server programs.

[1] O.M.Lugovskaya & S.A.Stepanov, (1991) Sov. Phys. Crystallogr. **36**, 478-471.

Web input form

X-rays:

- ○ Wavelength (A):
- ○ Energy (keV):
- ◉ Characteristic line: Cu-Ka1 ?

Target:

- ◉ Crystal: Silicon ?
- ○ Other material: ?
- ○ Chemical formula: and density (g/cm^3):

Reflection:

Miller indices: 1 1 1

Database Options for dispersion corrections df1 , df2:

- ◉ Use X0h data (5-25 keV or 0.5-2.5 A) -- recommended for Bragg diffraction.
- ○ Use Henke data (0.01-30 keV or 0.4-1200 A) -- recommended for soft x-rays.
- ○ Use Brennan-Cowan data (0.03-700 keV or 0.02-400 A)
- ○ Compare results for all of the above sources.

Get X0h! Reset

GID_SL on the Web

Dynamical x-ray diffraction from strained crystals, multilayers and superlattices at usual and grazing incidence angles

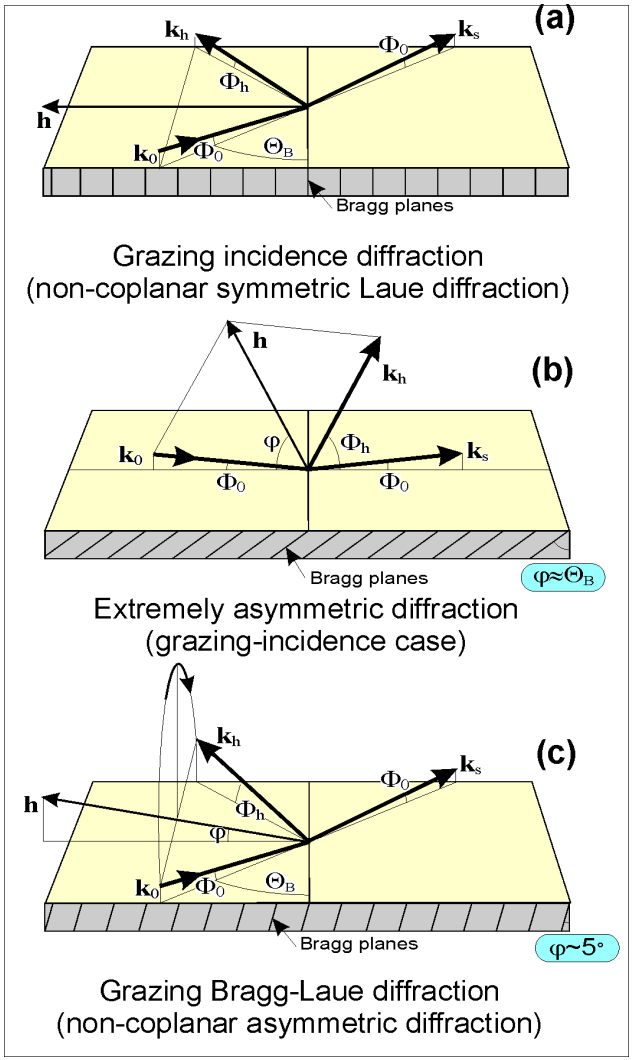
Background algorithm

GID_sl (Grazing Incidence Diffraction from Superlattices) was originally developed for GID (Fig.1a) from multilayers, but then extended to arbitrary Bragg case including coplanar (Fig.1b) and non coplanar asymmetric diffraction (Fig.1c).

The program can calculate Bragg diffraction from imperfect crystals with given profiles of normal lattice strains da(z)/a, dielectric susceptibilities $\chi_0(z)$, $\chi_h(z)$, and interface roughness height $\sigma(z)$.

The advantage of ***GID_sl*** over most of other Bragg diffraction simulation software is that it takes into account specular reflection and refraction of X-rays at crystal surface and interfaces in multilayers.

Replaces Takagi-Taupin equations for Grazing Incidence Diffraction!



S.A.Stepanov, E.A.Kondrashkina, R.Koehler, D.V.Novikov, G.Materlik, and S.M.Durbin,

Phys. Rev. B, v.**57**, No 8, p. 4829-4841, (1998).

GID_SL on the Web

Dynamical x-ray diffraction from strained crystals, multilayers and superlattices at usual and grazing incidence angles

Web input form

X-rays: Wavelength(A) / Energy(keV) = 1.540562 Line= Cu-Ka1 Polarization= Sigma

Crystal: GaAs X0h data (0.5-2.5A) Sigma= 0. A W0= 1. Wh= 1.

Bragg Reflection: 4 0 0 Substrate da/a= 0.

Geometry specified by: [5]. Surface orientation & condition of symmetric Bragg case

-- Geometry parameter ([1,7]=incidence angle, [2,8]=exit angle, [6]=Bragg planes angle, [9]=g0/gh):

-- Surface plane ([1-5]): 1 0 0 Miscut direction: 0 1 1 Miscut angle: 0. degr.

Scan axis: [k0 x h] Indices, if other scan axis: Invert scan axis

Scan limits: from -2000. to +2000. sec. Scan points= 401 Plot argument= incidence angle

watch progress Submit Query (single click, please!)

Top layer profile *(optional)*:

period=
t= sigma= da/a= code= x= code2= x2= code3= x3= code4= x0= xh= xhdf= w0= wh=
end period

```
period=20
t=100 code=GaAs sigma=2
t=70 code=AlAs sigma=2 da/a=a
end period
```

Available codes:

[?] **Crystals:**

AlAs
AlP
AlSb
AlYO3
BaTiO3
Beril
Beryllium

[?] **Non-crystals:**

Al2O3
B4C
BeO
BN
Cr2O3
CsI
Fluorite

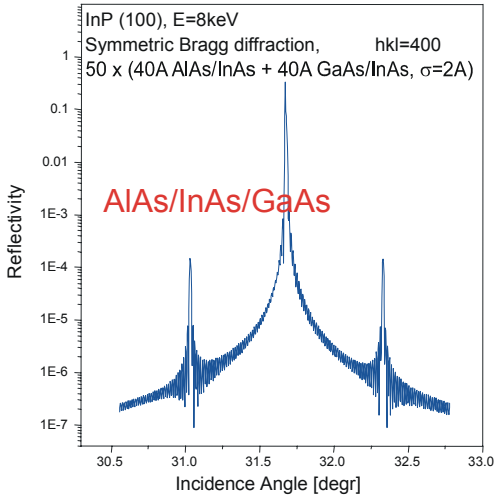
[?] **Elements:**

GID_SL on the Web

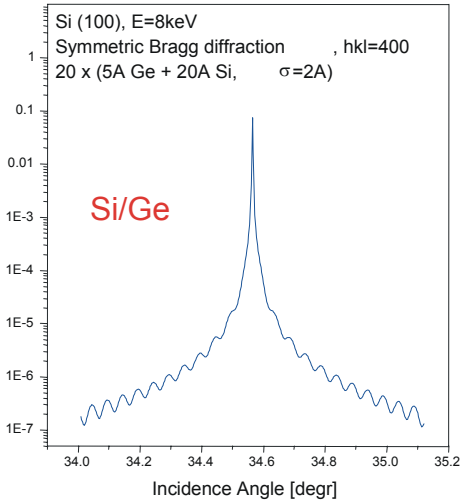
Dynamical x-ray diffraction from strained crystals, multilayers and superlattices at usual and grazing incidence angles

Example web results

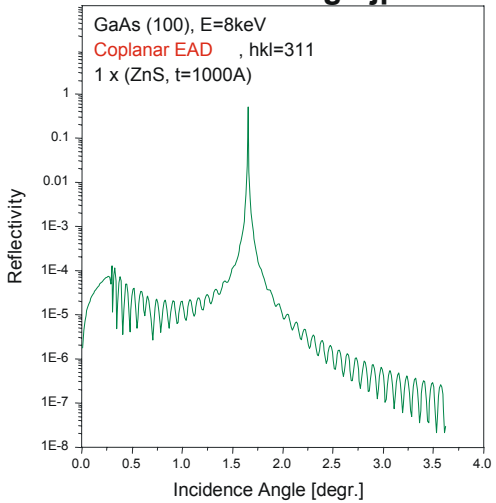
psu.edu



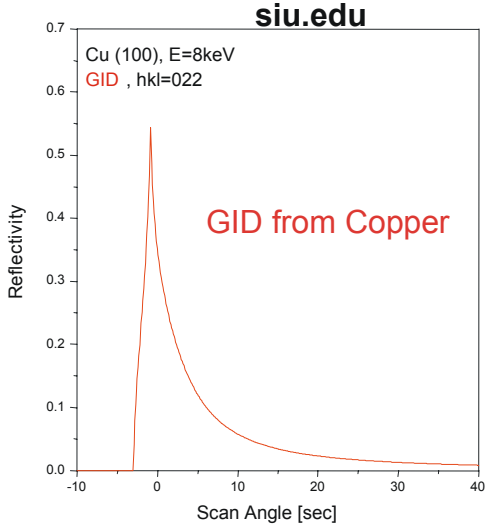
infn.it



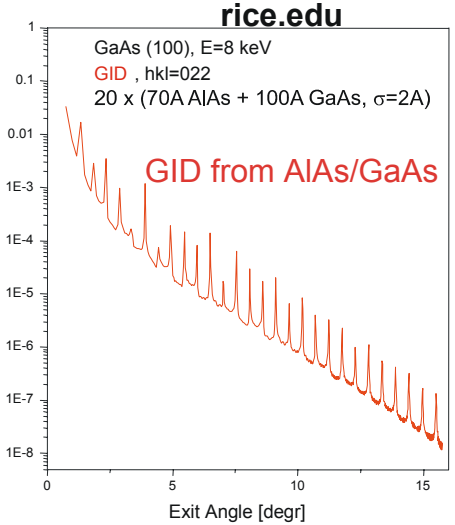
aist.go.jp



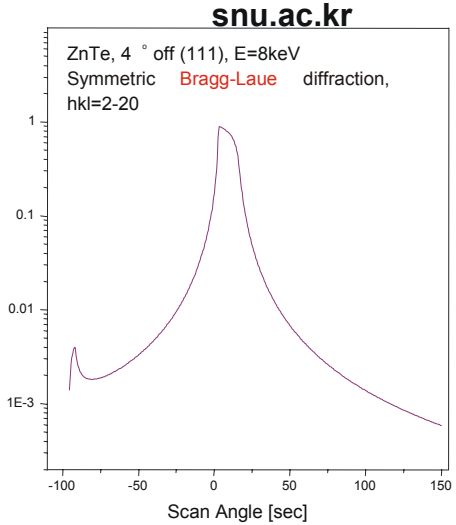
siu.edu



rice.edu



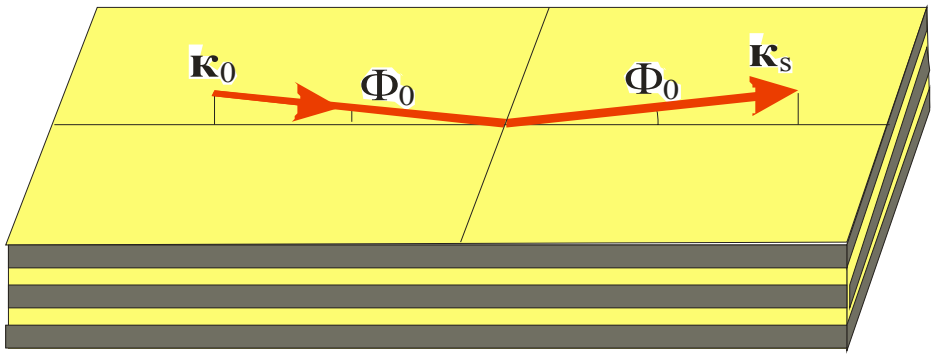
snu.ac.kr



Background model

TER_sl (Total External Reflection) software simulates X-ray specular reflection from multilayers with the account for interface roughness or transition layers using the same recursion algorithm as in ***GID_sl***.

The advantage of ***TER_sl*** over the well know Parratt recursive technique is a faster convergence of recursions because ***TER_sl*** expresses the reflection from a stack of N layers through the reflectivity of (N-1) layers, while the Parratt technique expresses the reflectivity of N-th layer via that of the underlying (N-1)-th layer.



By-product of ***GID_sl:***
same recursion algorithm !

S.A.Stepanov, E.A.Kondrashkina, R.Koehler, D.V.Novikov, G.Materlik, and S.M.Durbin, Phys. Rev. B, v.**57**, No 8, p. 4829-4841, (1998).

Web form

TER_SL on the Web

X-ray specular reflection from multilayers with rough interfaces at grazing incidence

X-rays: ◉ Wavelength(A) / ○ Energy(keV) = 1.540562 ○ Line= Cu-Ka1 ? Polarization= Sigma

Substrate: ◉ Database code: GaAs ? X0h data (5-25keV; 0.5-2.5A)

○ Chemical formula: rho= g/cm^3

○ Susceptibility x0 = ( ) / format: x0=(Re(x0), Im(x0)); note: x0=2*delta /

x0 correction: w0 = 1. / this is used as: x0 = w0 * x0 /

Roughness: sigma = 4. Angstrom **OR** Transition layer tr = 0. Angstrom

Incidence angle limits: from 0. to 3. degr. Scan points= 601

☑ **Standing waves:** Reference interface = 0 (0=surface)

Start offset = 0. Angstrom

End offset = 1000. Angstrom

Number of offsets = 101 (max = 401)

☐ **watch progress** Submit Query (single click, please!)

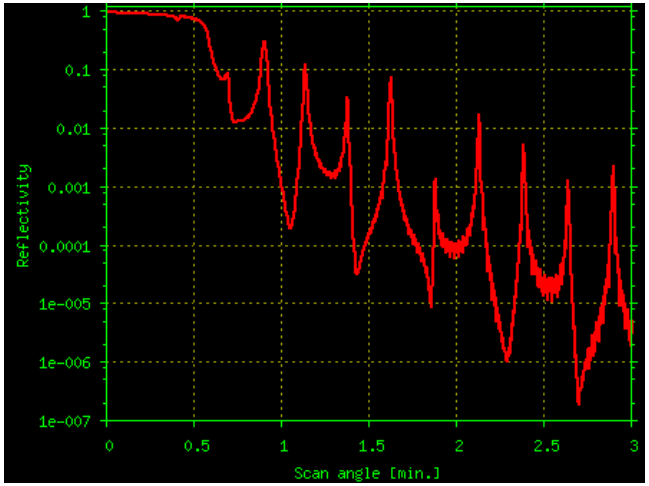
Top layer profile *(optional)*:

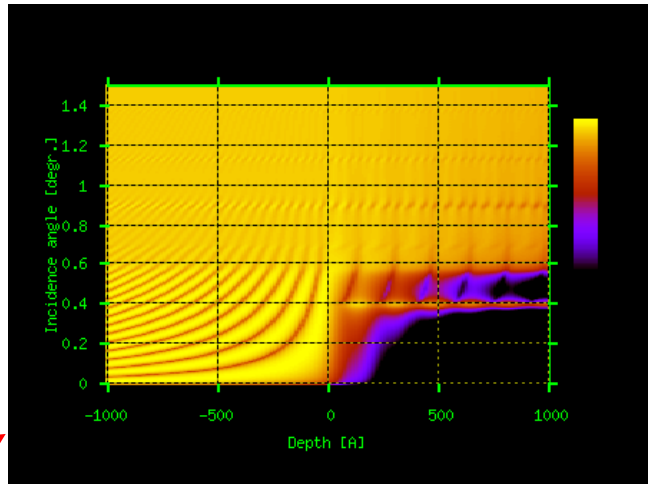
```
t=20 w0=0.5 sigma=5   !surface oxide, organic contamination or dust
period=20
t=100 code=GaAs sigma=4
t=70 code=AlAs sigma=4
end period
```

Submit Query (same "Submit" action as above; single click, please!)

Available codes:
(use Copy/Paste)

Ac
Ag
Al
Al2O3
AlAs
AlFe3
AlN
AlP





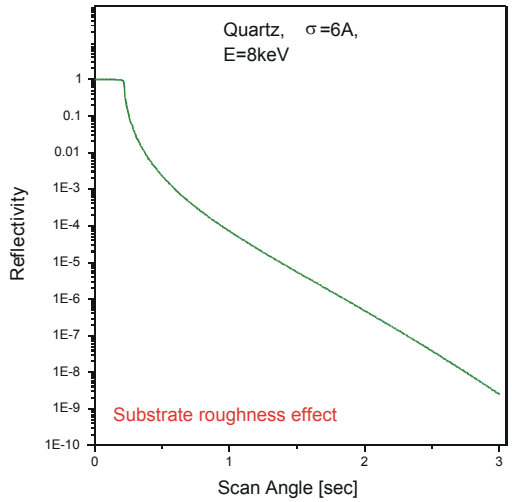
Recently added wavefields calculations for applications like fluorescence yield analysis, X-ray standing waves method, GISAXS, and etc.

TER_SL on the Web

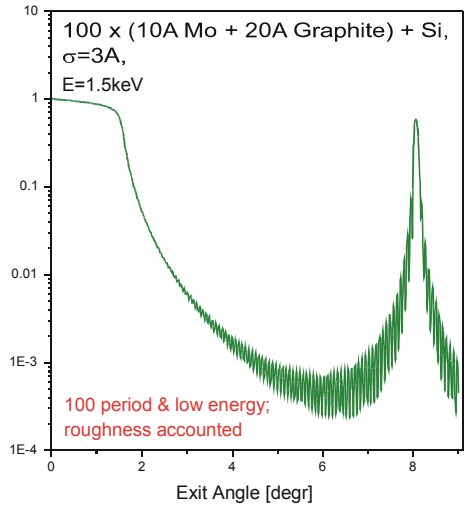
X-ray specular reflection from multilayers with rough interfaces at grazing incidence

Example web results

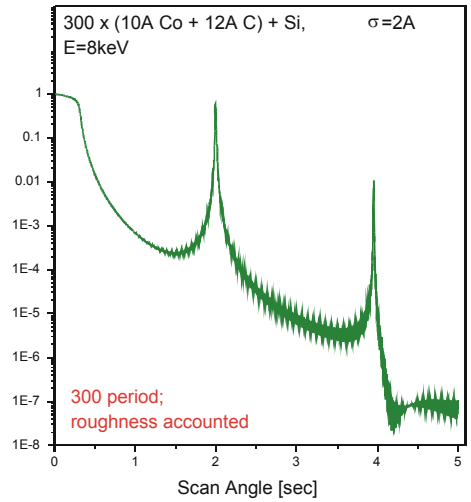
samsung.co.kr



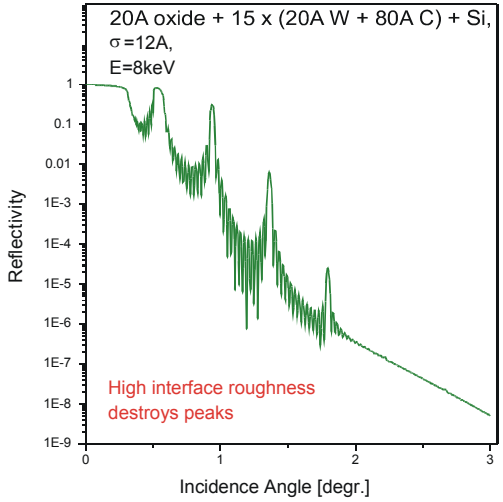
aps.anl.gov



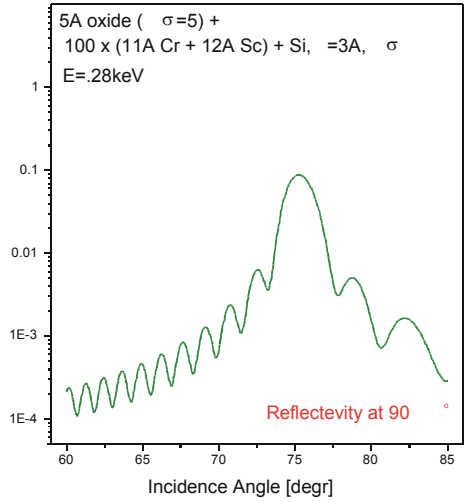
zeus.kharkiv.net



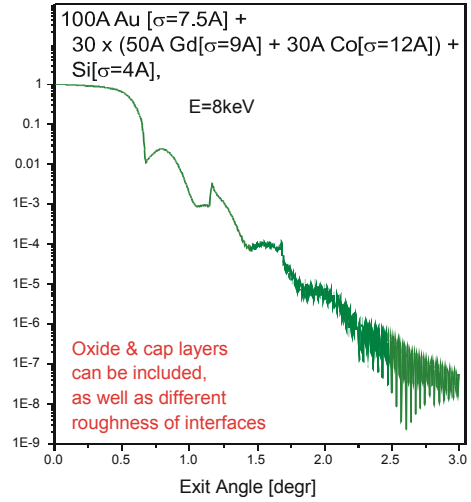
uni-muenchen.de



iof.fhg.de

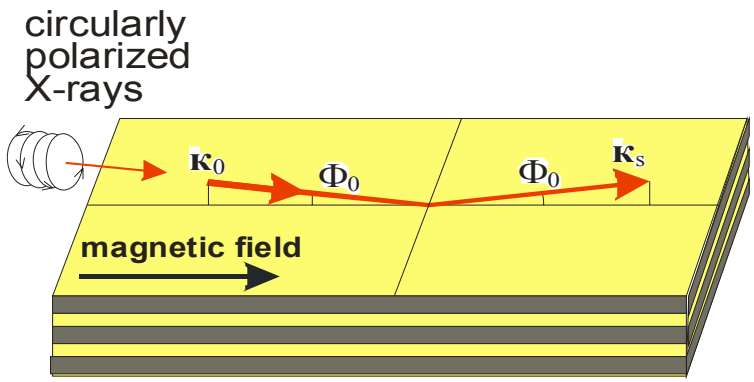


siemens.de



Background algorithm

The ***MAG_sl*** program solves the problem of resonant X-ray reflectivity from magnetic multilayers. The major application of X-ray resonant magnetic scattering is to probe thin magnetic films and magnetic multilayers. This is a hot topic related to studying magnetic heads for computer hard drives. However, since in this case the media susceptibility is a tensor, the conventional Parratt technique for calculating X-ray specular reflection is not applicable. The problem is solved in ***MAG_sl*** applying a recursive algorithm for (2x2) scattering matrices similar to that of ***GID_sl***.



S.Stepanov and S.Sinha, Phys. Rev. B, **61** (2000) 15302-15311.

D.R.Lee, S.K.Sinha, D.Haskel, Y.Choi, J.C.Lang, S.A.Stepanov, and G.Srajer, Phys. Rev. B, **68** (2003) 224409-224427.

MAG_SL on the Web

X-ray resonant specular reflection from magnetic multilayers

Web form

X-rays: Wavelength(A) / Energy(keV) = 7.243 Line=

Polarization: 4. Circular - angle to Sigma-plane for Option-3 0.

Substrate: Database code: Silicon X0h data (5-25keV; 0.5-2.5A)

Chemical formula: rho= g/cm^3

Susceptibility x0 = ( ) / format: x0=(Re(x0), Im(x0)); note: x0=2*delta /

x0 correction: w0 = 1. / this is used as: x0 = w0 * x0 /

Roughness: sigma = 0. Angstrom **OR** Transition layer tr = 0. Angstrom

Magnetic atoms share (0.--1.) / density (1/cm^3): 0.

Magnetic orientation X = 0 Y = 0 Z = 0

Magnetic amplitudes F10 = 0., 0. F11 = 0., 0. F1T = 0., 0.

Scan (incidence angle or qz): from 0. to 4. degr. Scan points= 4001

Magnetic model: generic (may have numeric problems for hard x-rays) / hard x-rays (E>6keV)

watch progress Submit Query (single click, please!)

Top layer profile *(optional)*:

```
period=
 t= sigma= tr= code= rho= x= code2= x2= code3= x3= code4= x0= w0=
                    mshare= mdensity= mvector= F10= F11= F1T=
end period
```

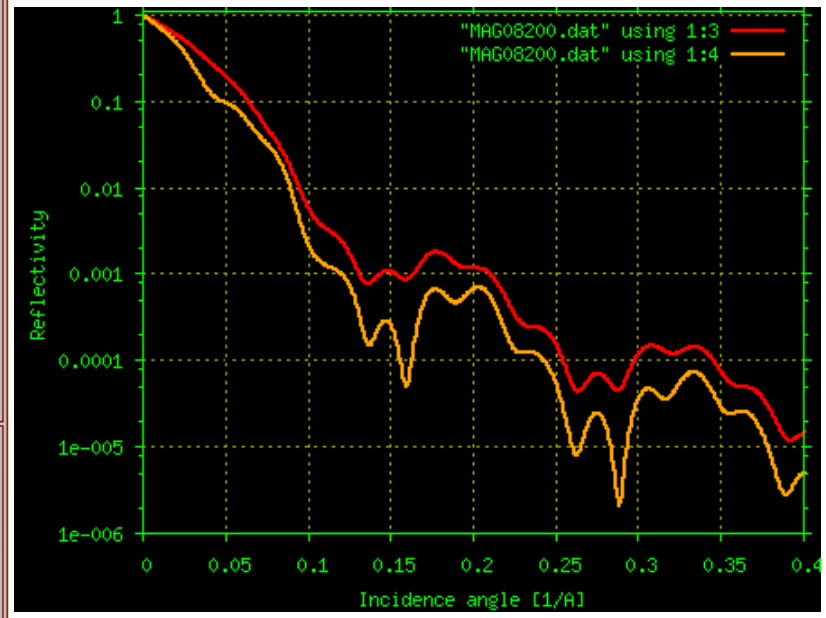
```
period=15
code=Gd t=50 F11=(-0.22,9.35) F1T=(0.37,9.65) mshare=1 mvector=(1 0 0)
code=Fe t=35
end period
```

Submit Query (same "Submit" action as above; single click, please!)

Available codes: (use Copy/Paste)

Ac
Ag
Al
Al2O3
AlAs
AlP
AlSb
AlYO3
Am
Ar
As
At
Au
B
B4C

More details



MAG_sl example: difference between reflectivity of circular-plus and circular-minus polarized X-rays at E=849eV from 47A capped Ni film.

Background algorithm - I

TRDS_sl (Total Reflection Diffuse Scattering from Superlattices) was developed for the simulations of X-ray diffuse scattering from interface roughness in multilayers (Fig.1). This program implement a number of different models for interface roughness and for correlations between roughness at different interfaces in multilayers (Fig.2). Notable is the implementation of the model allowing to study wavelength-dependent inheritance of roughness in layer-by-layer grown multilayers (Fig.3).

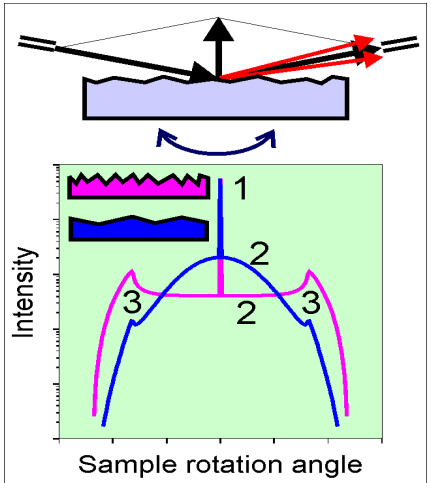


Fig.1. Diffuse scattering of grazing x-rays from surface roughness. 1: specular peak, 2: diffuse scattering for two different lateral scales of roughness, 3: Yoneda peaks at critical angle for total reflection.

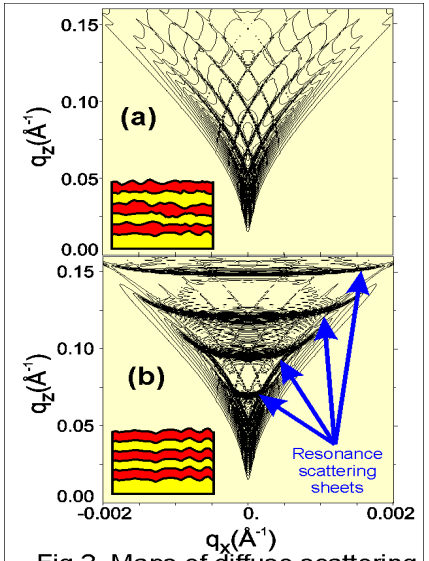


Fig.2. Maps of diffuse scattering from vertically uncorrelated (a) and correlated (b) roughness

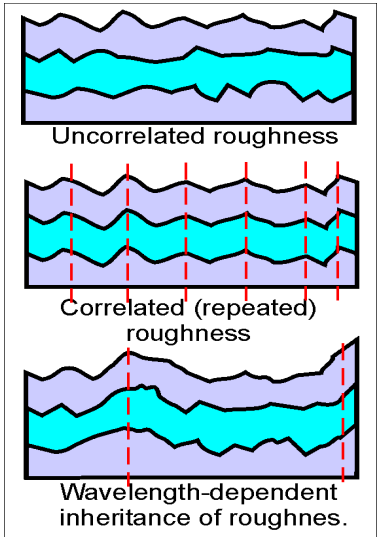


Fig.3. Different models of roughness correlations in multilayers

V.M.Kaganer, S.A.Stepanov & R.Koehler, (1995) Phys. Rev. B **52**, 16369-16372.

Background algorithm - II

Other notable models implemented in ***TRDS_sl*** are the X-ray scattering from atomic steps on vicinal interfaces and the scattering due to inclined roughness transfer in crystalline multilayers (Fig.4). Both of those effects provide asymmetry of x-ray diffuse scattering (Fig.5), but each of different kind.

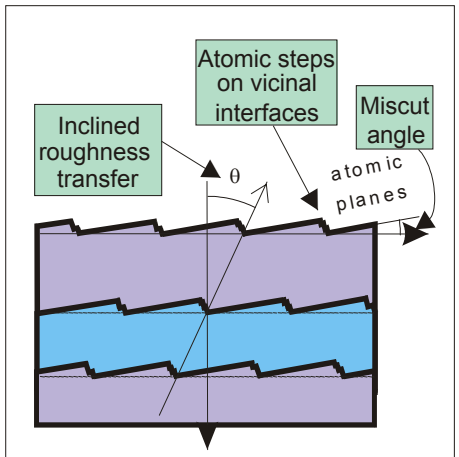


Fig.4. Asymmetric rougness of vicinal interfaces and skew roughness transfer in crystals.

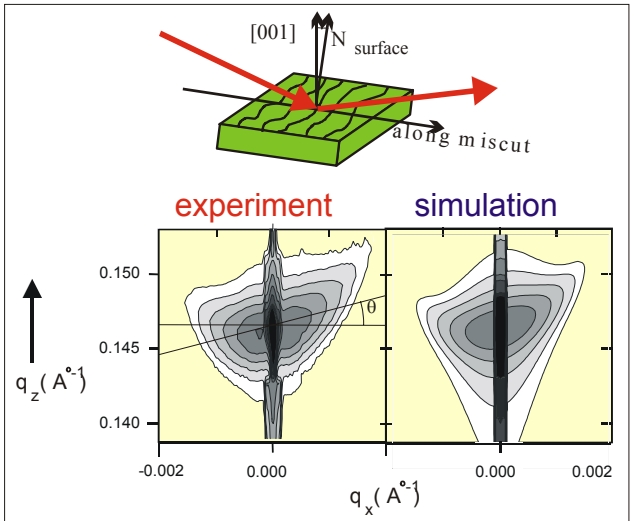


Fig.5. Simulations of inclined roughness transfer in AlAs/GaAs superlattice.

E.A.Kondrashkina, S.A.Stepanov, R.Opitz, M.Schmidbauer, R.Koehler, R.Hey, M.Wassermeier, and D.V.Novikov,

Phys. Rev. B, v.**56**, No 16, p. 10469-10482, (1997).

Web form

X-rays: Wavelength(A) / Energy(keV) = 1.540562 Line= Cu-Ka1 Polarization= Sigma

Substrate: Database code: GaAs X0h data (5-25keV; 0.5-2.5A)
Chemical formula: rho= g/cm^3
Susceptibility x0 = ( ) / format: x0=(Re(x0), Im(x0)); note: x0=2*delta /
x0 correction: w0 = 1. / this is used as: x0 = w0 * x0 /
Roughness: sigma = 3. Angstrom / this is rms roughness height /

Type of scan: Q-scans at fixed 2Q Units for Q,2Q: degr. Units for qx,qz: 1/A
Scan limits: from 0. to 2. points= 201
Offset limits: from 2. to 2. points= 1
Compute at specular rod: scattering reflection

Accelerators: Use K instead of exp(K)-1 Use semi-Born approximation

Roughness: lateral correlation length= 1000. A vertical correlation length= A jaggedness= 1.
angle of skew transfer= 0. degr.

Models:
- Uncorrelated roughness
- Completely correlated roughness
- Ming's model
- Lagally's model — lateral size of vertically correlated roughness= A
- Holy's model
- Spiller's model (*very slow!*)
- **Data for all Pukite's models:** miscut angle= degr. Add affine roughness
  - Classic Pukite's model
  - Smoothed Pukite's model — effective rms height of steps= A
  - Pershan's model — terraces size spread= A

watch progress Submit Query (single click, please!)

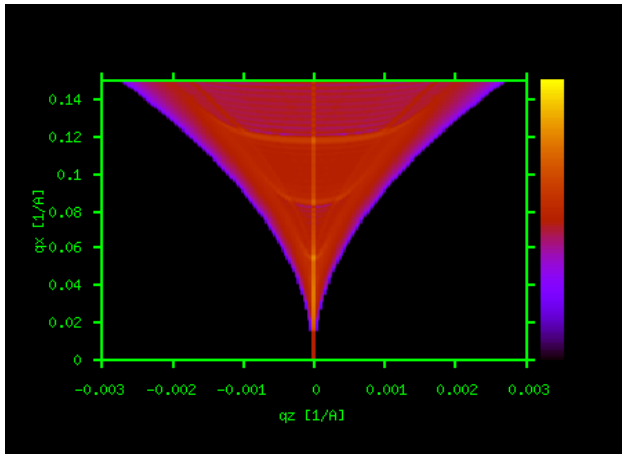
Top layer profile *(optional)*:
period=
t= sigma= tr= code= rho= x= code2= x2= code3= x3= code4= x0= w0=
end period

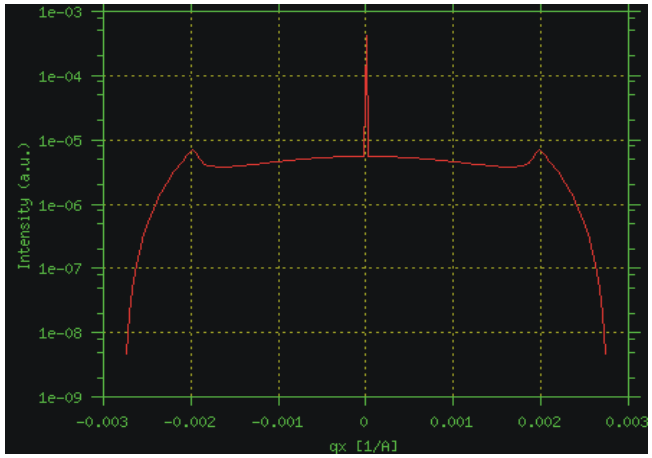
Available codes:
(use Copy/Paste)
Ac
Ag
Al
Al2O3

TRDS_3L on the Web

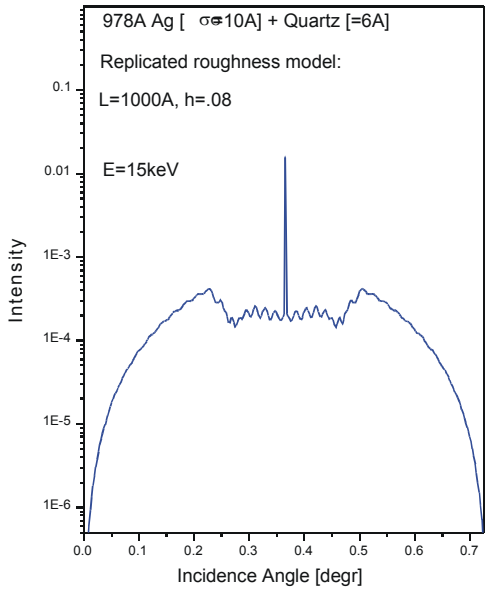
X-ray diffuse scattering at grazing incidence from surface and interface roughness

Example web results

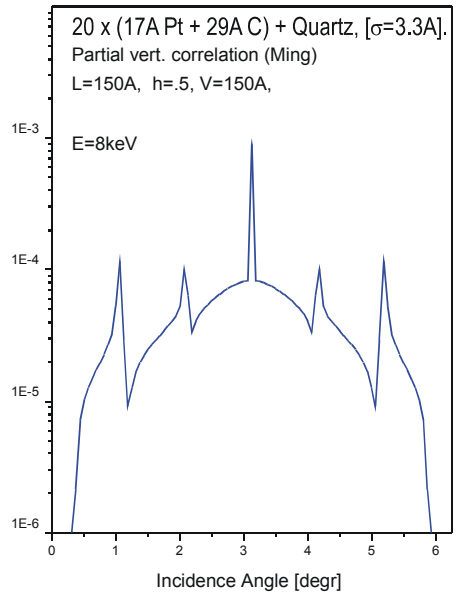




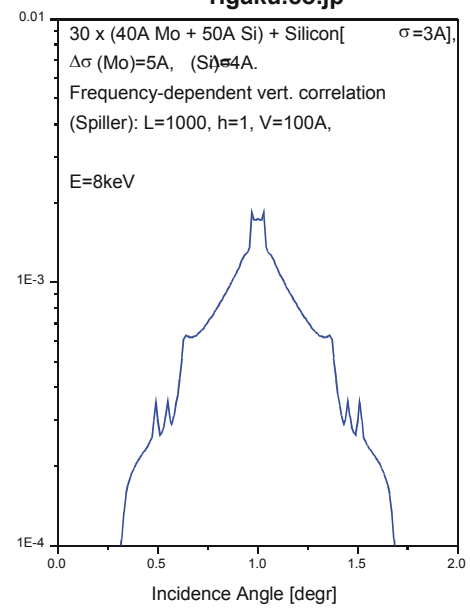
uni-duesseldorf.de



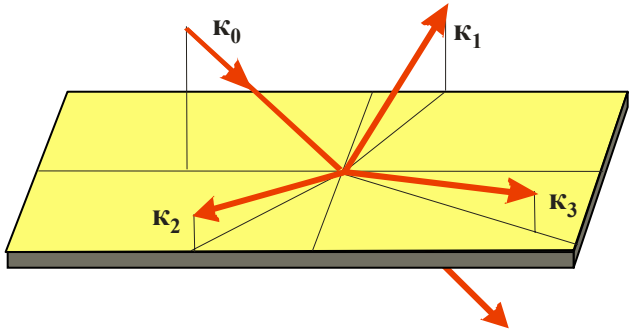
iisc.ernet.in

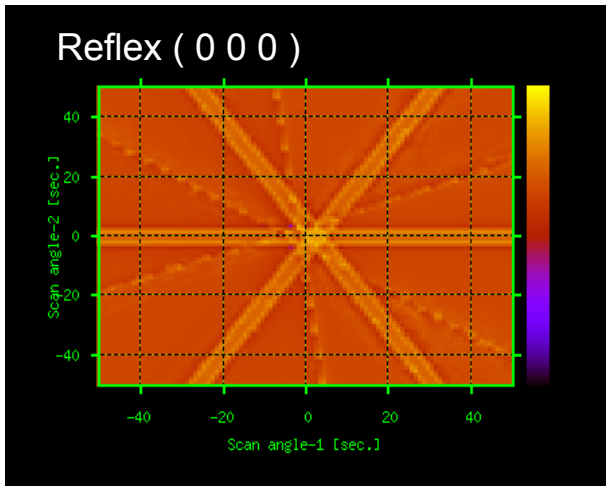


rigaku.co.jp



Background algorithm





Kossel lines in case of multiple Bragg diffraction

BRL (Bragg/Laue) calculates multiple Bragg diffraction patterns with the algorithm based on the extended dynamical diffraction theory.

Typically the calculations of multiple Bragg diffraction are reduced to the eigenvalue problem for a **2N*2N** scattering matrix. However, when the diffraction geometry involves grazing X-ray waves, the calculations are reduced to the eigenvalue problem for **4N*4N** scattering matrix [Colella, Acta Cryst. **A30** (1974) 413].

BRL implements an algorithm where the calculations are reduced to a *generalized* eigenvalue problem for **2(N+Ns)*2(N+Ns)** scattering matrix where Ns is the number of grazing waves. Thus, if there are no grazing waves, the matrix size is 2N*2N and if all of the waves are grazing it becomes 4N*4N. In some cases the calculations are reduced dramatically.

S.Stepanov and A.Ulyanenkov, Acta Cryst. **A50** (1994) 579-585.

BRL on the Web
X-ray multiple Bragg/Laue diffraction

Web form

Target:

Crystal: Silicon

Surface: Base plane: 1 1 1

Miscut direction: 1 -1 0

Miscut angle: 0. degr.

Reflections:

Reflex-1: 1 1 1

Reflex-2: 2 2 0

Index search range: 5

Min. Intensity filter: 0.1
(|xh/x0|*100% > ...)

X-rays:

- Wavelength (A):
- Energy (keV):
- Characteristic line: Cu-Ka1
- Fixed by coplanar case
- Fixed by Reflex-3:

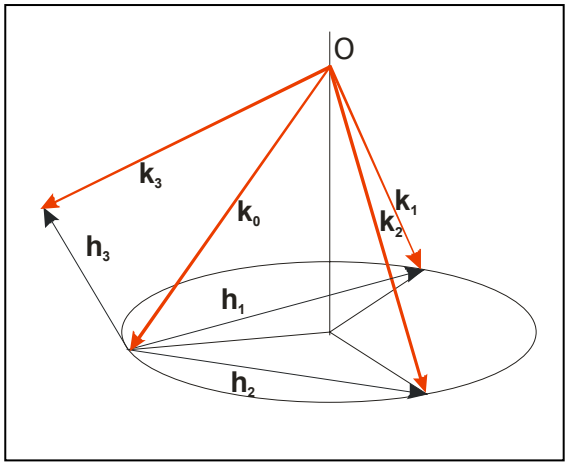
Database Options for dispersion corrections df1, df2:

- Use X0h data (5-25 keV or 0.5-2.5 A) -- *recommended*
- Use Henke data (0.01-30 keV or 0.4-1200 A)
- Use Brennan-Cowan data (0.03-700 keV or 0.02-400 A)

Submit Reset

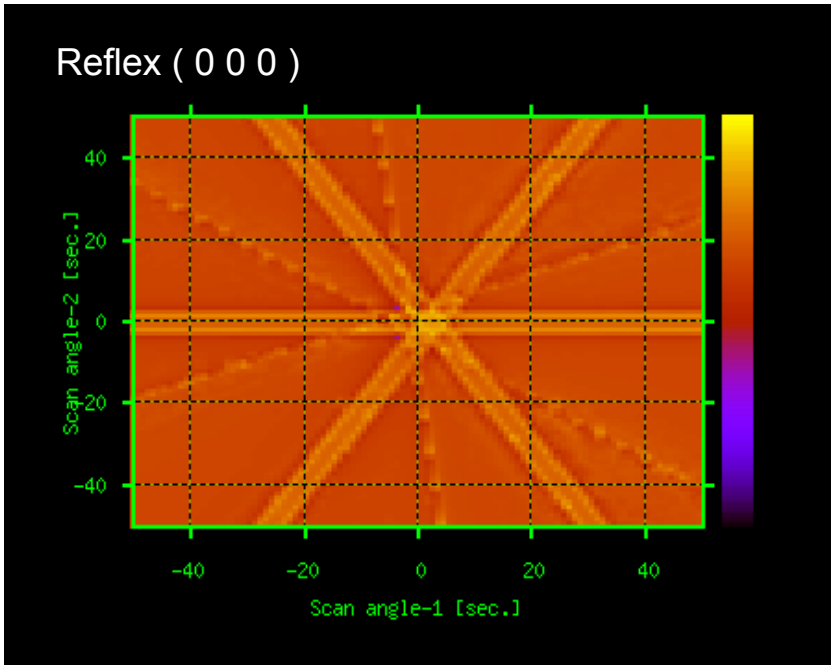
This is a Step-1 input form where one defines diffraction geometry. It calls an auxiliary program that looks for multiple diffraction combinations and generates Step-2 form.

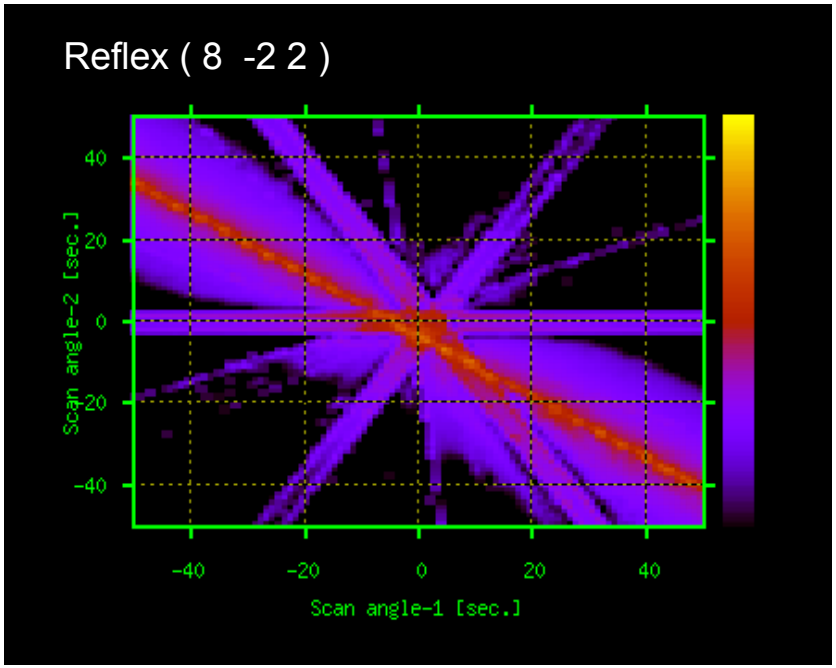
At Step-2 user can enter scan parameters and include additional reflections if they were found and then call ***BRL*** to perform the multiple diffraction calculations.



Example web results

monash.edu.au

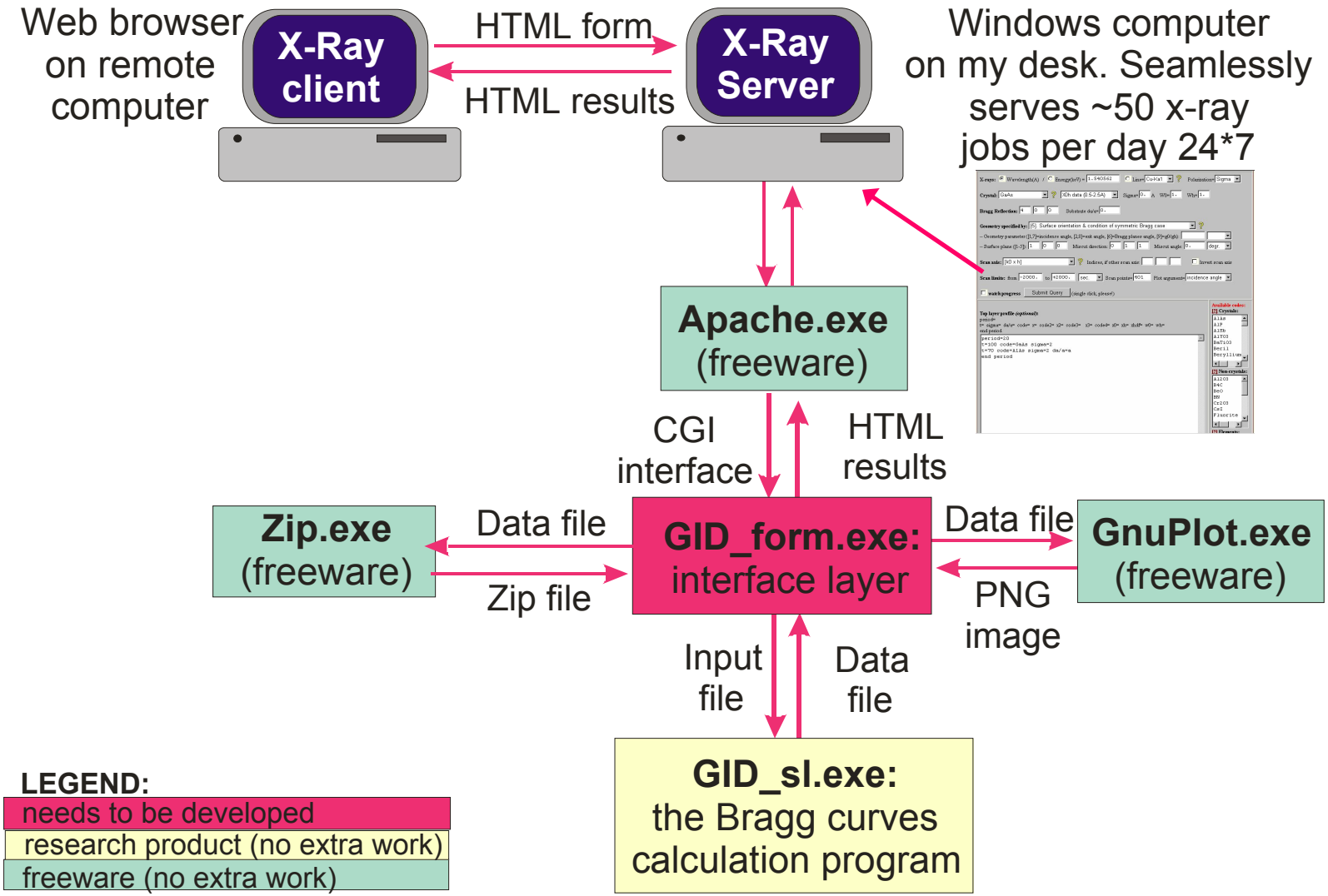




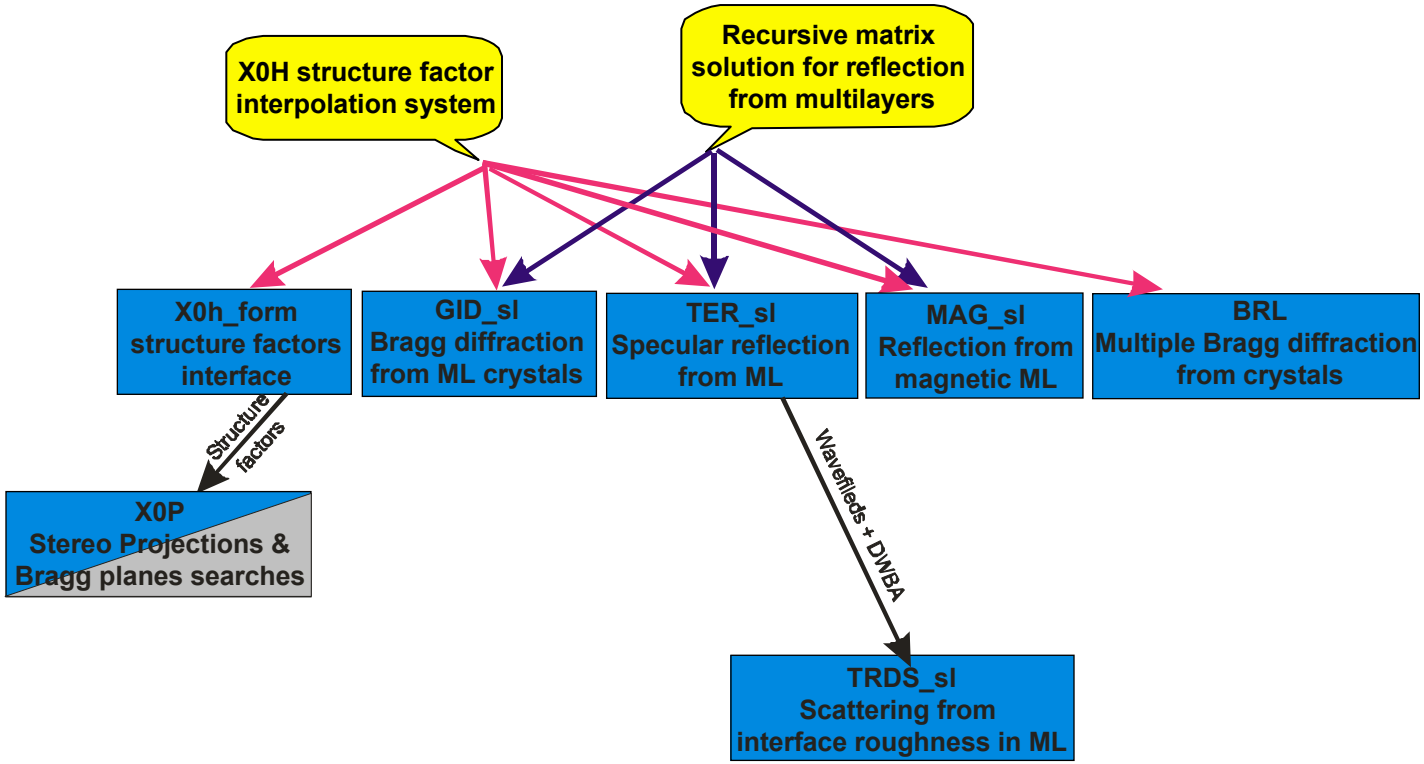
Some maps produced by 10-wave case calculations

(Silicon, λ= 0.6968004107A)

How it works: is it much effort to make software WWW-accessible?

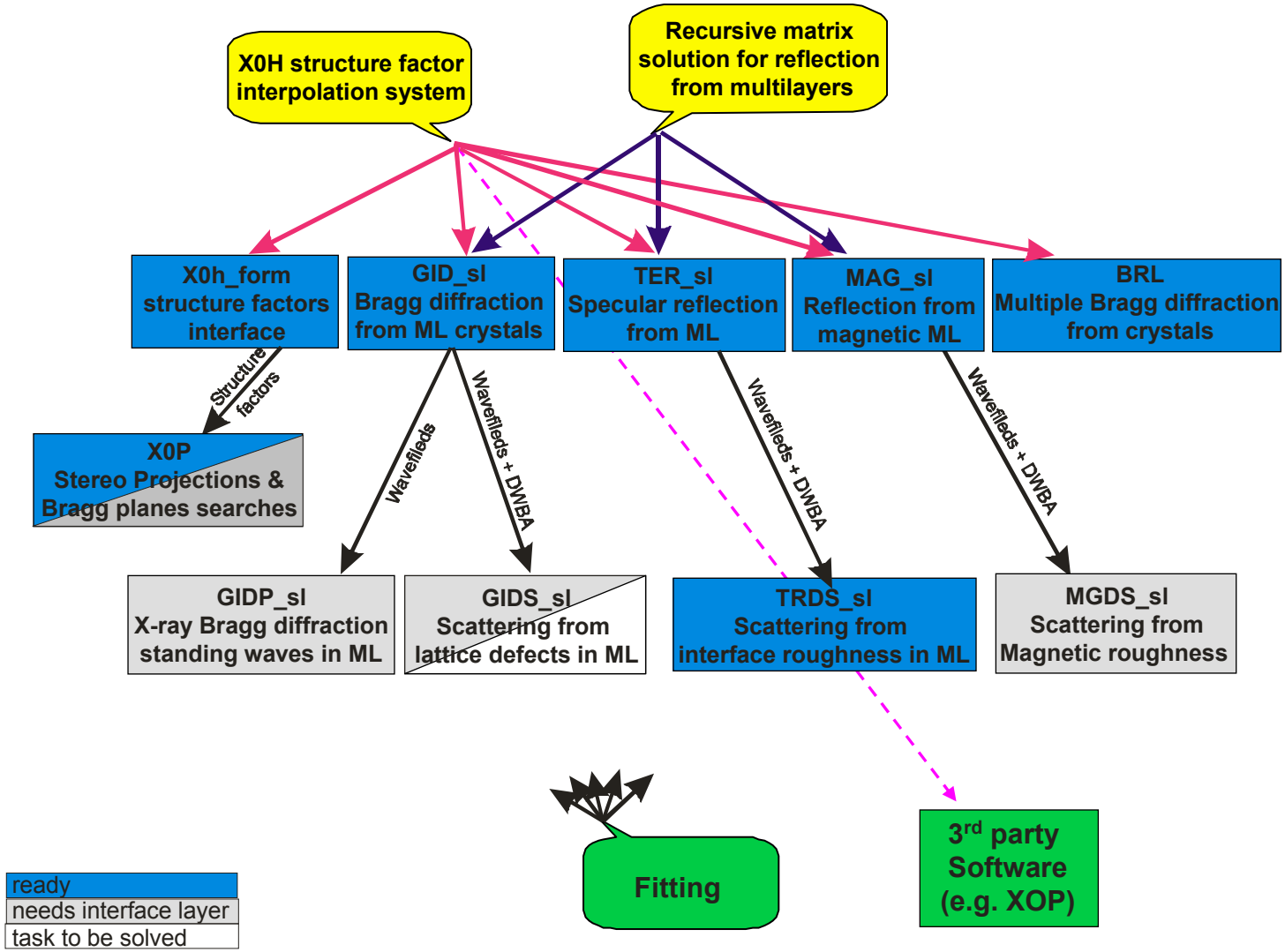


Server development: present structure



ready
needs interface layer
task to be solved

Server development: future plans



Server development: fitting *vs.* automation – I

X-rays: Wavelength(A) / Energy(keV) = 1.540562 Line= Cu-Ka1 ? Polarization= Mixed

Crystal: SiC-4H ? XOh data (0.5-2.5A) Sigma= 0. A W0= 1. Wh= 1.

Bragg Reflection: 0 0 12 Substrate da/a= 0.

Geometry specified by: angle of Bragg planes to surface ('+' for g0>gh) , Value: 0. degr.

Scan: from -14000 to +4000. sec. Scan points: 401 Invert axis: Plot argument: incidence angle

Approximations: alpha_max= 1.E+8 *|xh| ?

watch progress Submit Query (single click, please!)

Top layer profile *(optional)*:

period=

t= sigma= da/a= code= x= code2= x2= code3= x3= code4= x0= xh= xhdf= w0= wh=

end period

```
t=800 da/a = 0.00048 wh= 0.971610767
t=800 da/a = 0.00048128 wh= 0.97153615
t=800 da/a = 0.00048128 wh= 0.97153615
t=800 da/a = 0.00048512 wh= 0.971312334
t=800 da/a = 0.0004864 wh= 0.97123774
t=800 da/a = 0.00049024 wh= 0.971013993
t=800 da/a = 0.00049408 wh= 0.970790297
t=800 da/a = 0.0004992 wh= 0.970492116
t=800 da/a = 0.0005056 wh= 0.970119519
t=800 da/a = 0.00051328 wh= 0.969672591
t=800 da/a = 0.00052224 wh= 0.969151435
t=800 da/a = 0.00053376 wh= 0.968481789
t=800 da/a = 0.00054656 wh= 0.96773828
t=800 da/a = 0.0005632 wh= 0.966772572
t=800 da/a = 0.00058112 wh= 0.965733657
t=800 da/a = 0.0006016 wh= 0.964547692
t=800 da/a = 0.00062336 wh= 0.963289201
t=800 da/a = 0.00065536 wh= 0.96144146
t=800 da/a = 0.00068608 wh= 0.959670963
t=800 da/a = 0.0007168 wh= 0.957903727
t=800 da/a = 0.0007616 wh= 0.955332339
```

Submit Query (same "Submit" action as above; single click, please!)

Available codes:

[?] Crystals: AlAs, AlFe3, AlN, AlP, alpha-Fe, AlSb, AlYO3

[?] Non-crystals: Al2O3, B4C, BeO, BN, Cr2O3, CsI, Fluorite

[?] Elements: Ac, Ag, Al, Am, Ar, As, At, Au

Providing fitting for general case is non-practical:

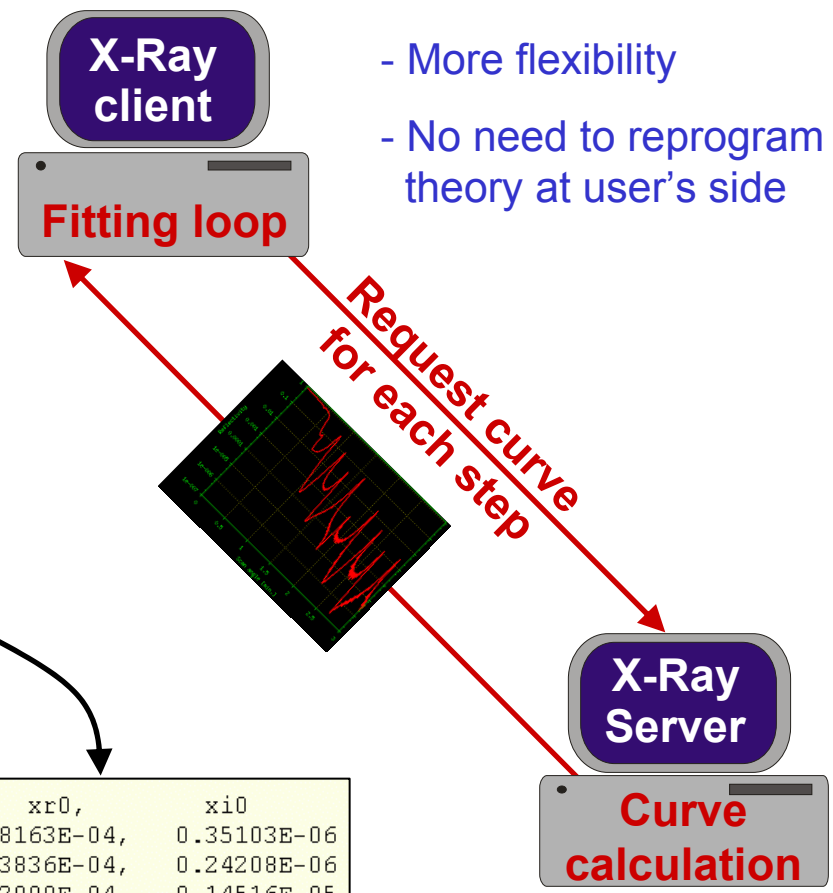
Too many parameters!

The form at the left is a typical material science application submitted from univ-poitiers.fr. The profile contains 72 lines, i.e. more than 200 parameters.

Server development: fitting *vs.* automation – II

```
#!/usr/bin/perl -W
  use LWP::Simple;        # World-Wide Web library for Perl (libwww-perl)
  my $file = "example.dat";
  my ($E1,$E2) = (10,12); # start and end energy
  my $n  = 3;             # number of pts (please stay within a few dozen!)
  my $dE = ($E2-$E1)/($n-1);
  my $url = "http://sergey.gmca.aps.anl.gov/cgi/X0h_form.exe";
  my $xway = 2;           # 1 - wavelength, 2 - energy, 3 - line type
  my $wave = 0;           # works with xway=2 or xway=3
  my $line = '';          # works with xway=3 only
  my $coway = 0;          # 0=crystal, 1=other material, 2=chemicalformula
  my $code = 'Germanium'; # works with coway=0 only
  my $amor = '';          # works with coway=1 only
  my $chem = '';          # works with coway=2 only
  my $rho = '';           # works with coway=2 only
  my ($i1,$i2,$i3) = (0, 0, 0); #Miller indices
  my $df1df2 = 0;         # DB Option for dispersion corrections:
  my $modeout = 1;        # 0 - html out, 1 - quasy-text out with keywords
  my $detail  = 0;        # 0 - don't print coords, 1 = print coords
  open (DAT,">", $file) || die "Can't open ${file}\n";
  print DAT "#Energy,      xr0,        xi0\n";
  for (my $i=0; $i<$n; $i++) {                    # Energy loop
    $wave = $E1 + $dE * $i;
    my $addr="${url}?xway=${xway}&wave=${wave}&line=${line}&coway=${coway}".
             "&code=${code}&amor=${amor}&chem=${chem}&rho=${rho}".
             "&i1=${i1}&i2=${i2}&i3=${i3}&df1df2=${df1df2}".
             "&modeout=${modeout}&detail=${detail}";
    my $buffer = get($addr);                      #Request X0h data from WWW
    my @content = split /\n/, $buffer;            # split page into lines
    my $ncon = $#content + 1;                     # number of lines on page
    print DAT "   ${wave},";
    for (my $j=0; $j<$ncon; $j++) {               # loop over page lines
      my $x = $content[$j]; chop $x;              #strip LF/CR
      if ( $x =~ m/xr0=/ ) {$x =~ s/^.*xr0=//g; print DAT "  ${x},";}
      if ( $x =~ m/xi0=/ ) {$x =~ s/^.*xi0=//g; print DAT "  ${x}\n";}
    }
  }
```

Perhaps a more productive idea than online fitting is to provide tools to grab data by a fitting procedure running at a remote computer:

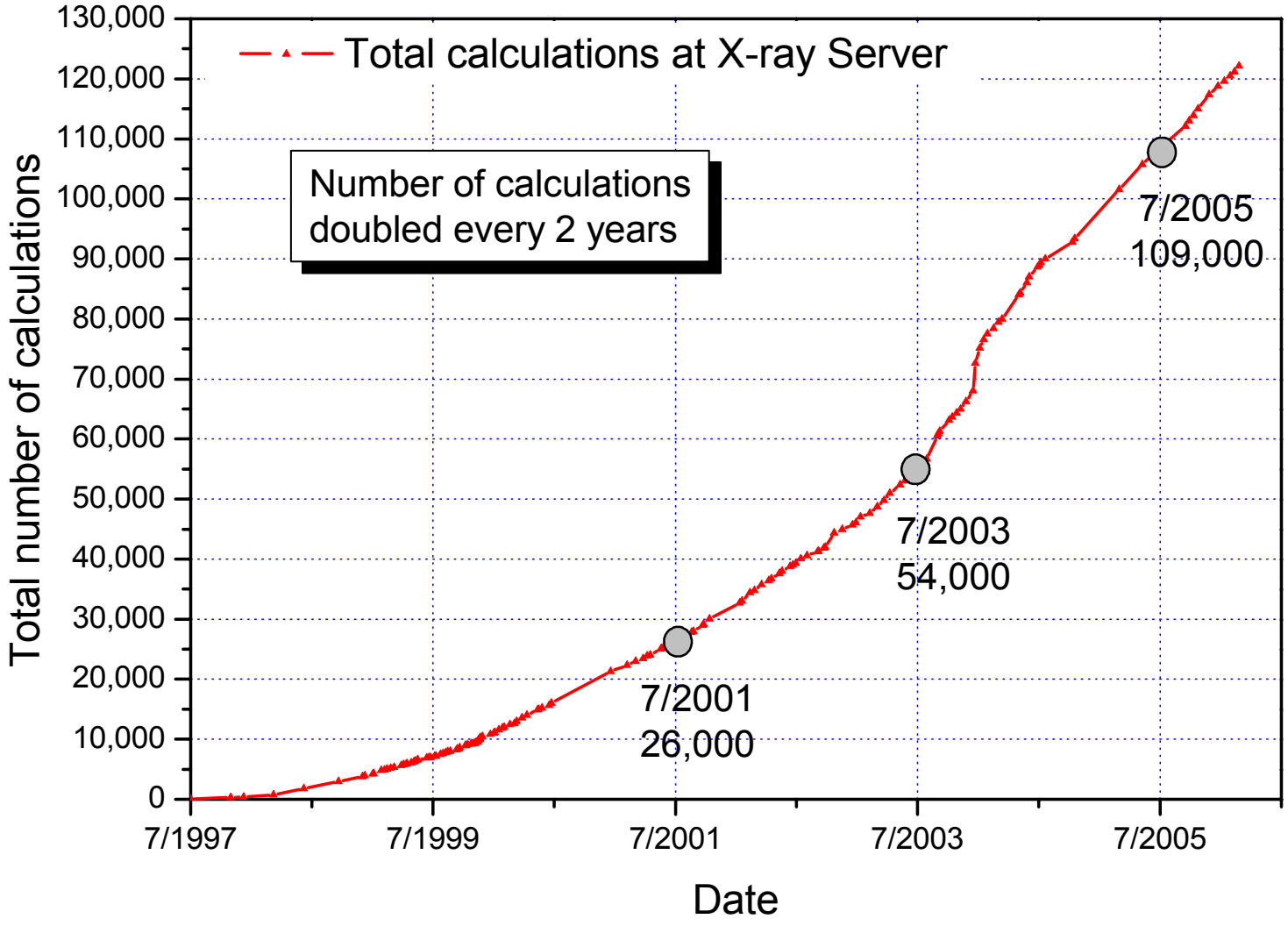


- More flexibility
- No need to reprogram theory at user's side

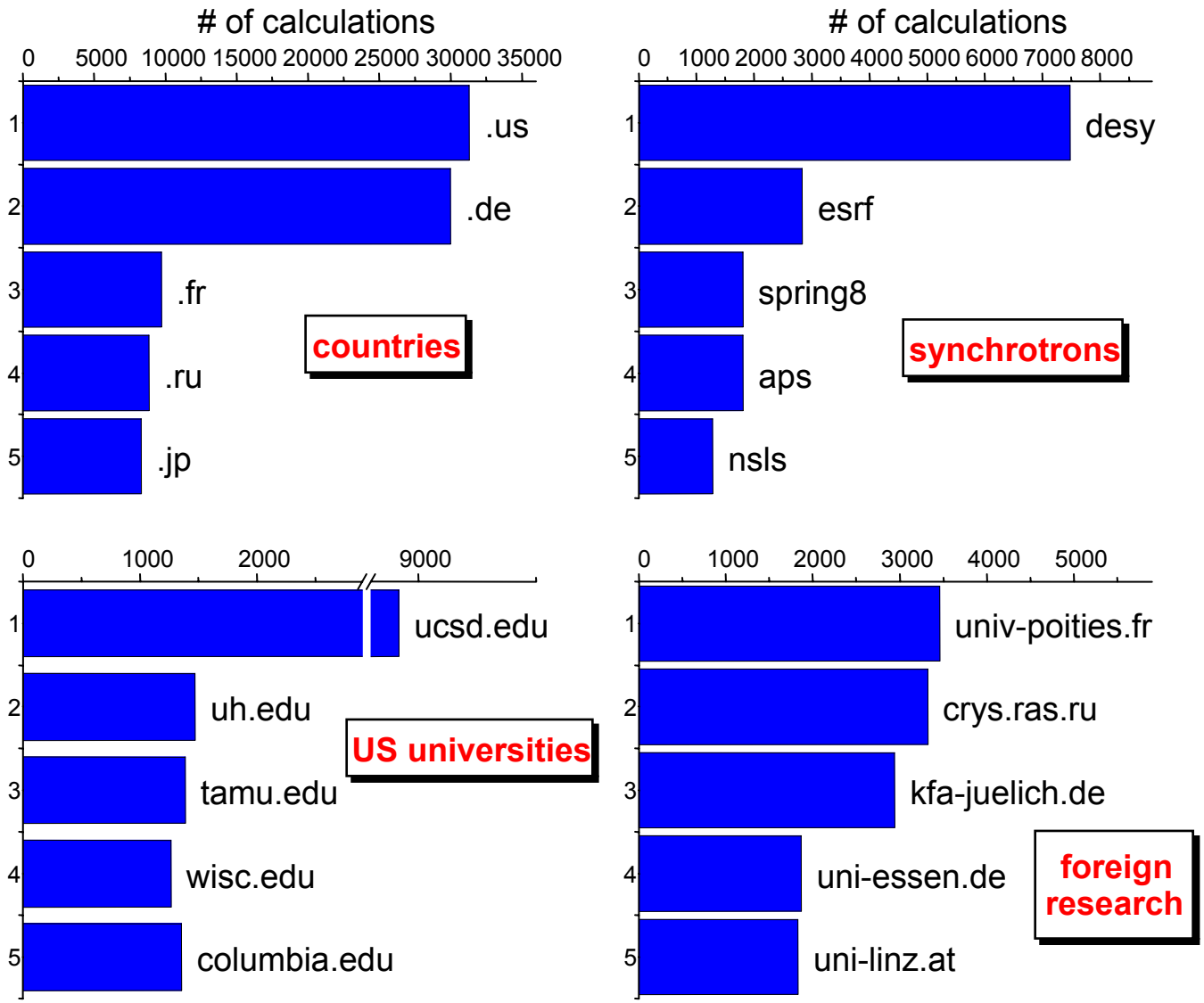
Example script provided on the server to request & save χ_{0r} and χ_{0h} as a function of X-ray energy

```
#Energy,      xr0,         xi0
   10,  -0.18163E-04,   0.35103E-06
   11,  -0.13836E-04,   0.24208E-06
   12,  -0.12809E-04,   0.14516E-05
```

Some X-ray Server statistics



Some X-ray Server statistics (continued)



monash-edu.au

Acknowledgements

Co-authors of algorithm presented through the X-ray Server:

S.Durbin, T.Jach, B.Jenichen, V.Kaganer, R.Koehler, E.Kondrashkina, O.Lugovslaya, G.Materlik, D.Novikov, U.Pietsch, S.Sinha, A.Souvorov, A.Ulyanenkov.

X-ray Server users contributed by their feedback:

B.Barnes, A.Van der Lee, G.Bertschinger, D.Black, C.Blome, W.Cai, G.Ceriola, K. Chandrasekaran, H.Chapman, Y.Danon, A.Declemy, C.Dufour, R.Forrest, M.Dias Franco, M.Grundmann, E.Gullikson, L.Hudson, E.Ikonen, C.-C.Kao, J.Langer, B.Lings, J.Santiso, R. Medicherla, A. Fontcuberta-i-Morral, P.Muduli, P.Nilsson, C.Noyan, R.Osgood, F. Pfeiffer, E.Roa, X.Huang, D. Satapathy, D. Schroff, M. Servidori, X.Su, S.Warren, M.Weimer, M.Zhong, *and many others!*

X-ray Server hosts:

Management of BIO and GM/CA Collaborative Access Teams at the Advanced Photon Source for hosting X-ray Server on their computers. The GM/CA and BIO CATs are the research centers sponsored by the National Institutes of Health.