Crystals for X-Ray Spectrometry

The spectral analysis of X-rays emitted by a sample after irradiation is both a powerful qualitative and quantitative analytical technique. It is based on the following phenomenon: an atom relaxes after excitation by emitting X-ray radiations at specific wavelengths, which reveal the identity of the emitting species.

For this spectral analysis Saint-Gobain Crystals supplies two key components:

- The monochromating crystals
- The scintillation detectors

Monochromating crystals

A monochromating crystal behaves in X-ray spectrometry as does a diffraction grating in optics. When rotated with respect to the incident polychromatic beam (see figure), it will diffract the spectral component along with direction to satisfy Bragg's law, namely: $2d \sin \theta = n \lambda$ where integer n refers to the diffraction order.

Hence, the most important characteristic of a monochromating crystal is the double atomic spacing 2d, which gives the largest wavelength to be diffracted.

The range of monochromators supplied by Saint-Gobain Crystals can be found in the table (next page), along with the usual surface finish, within our control means, to the best intensity-resolution compromise. The optimum depends on each specific case and strongly reflects the nature of the set-up.

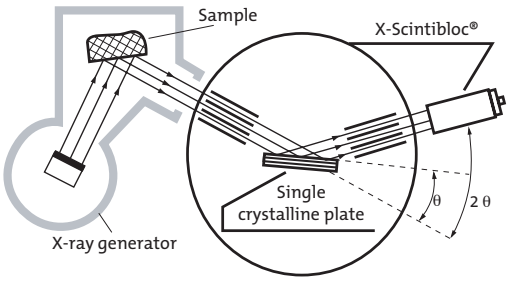
An X-ray spectrometer basically consists of:

An excitation source which may be either a primary X radiation, in which case one refers to X-ray fluorescence spectrometry. Or an electron beam, inducing a so-called direct emission, used in microprobes and scanning electron microscopes.

A monochromating crystal which is used to disperse the various spectral components of the incident beam.

A detector in order to measure the intensity of the various spectral lines as singled out by the monochromator.

The detector offered by Saint-Gobain Crystals combines a NaI(Tl) or Lanthanum Bromide scintillator directly coupled to a photomultiplier with a low absorbing MIB or beryllium entrance window (see brochure "Scintillation detectors").



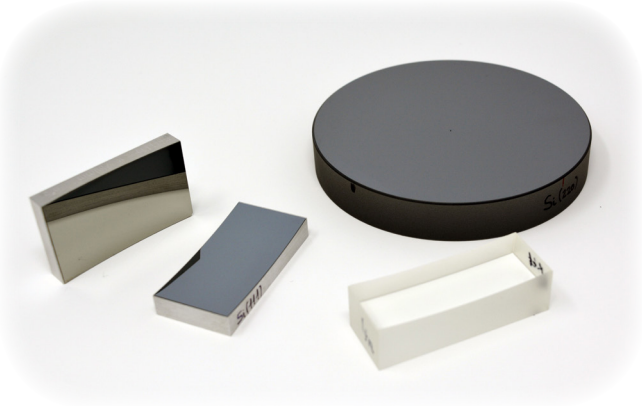
Products available

Monochromating crystals can be suppled in the two following shapes: Flat or Curved onto a holder

Flat plates can be supplied unmounted or mounted into holders suitable for industrial X-ray fluorescence spectrometers. Other types of holders may also be supplied on request. The standard orientation accuracy provided is 10 minutes. On special request a one-minute accuracy can be ensured.

The curved plates used in such instruments as microprobes and scanning electron microscopes are always supplied on tailor-made holders.
Two main types of focusing configurations may be considered:
The Johann geometry and The Johansson geometry

3D curved crystal optics can be provided according to your special finishing requirements:
spherical, toridal, ellipsoidal, conical, others (please inquire)



CRYSTALS

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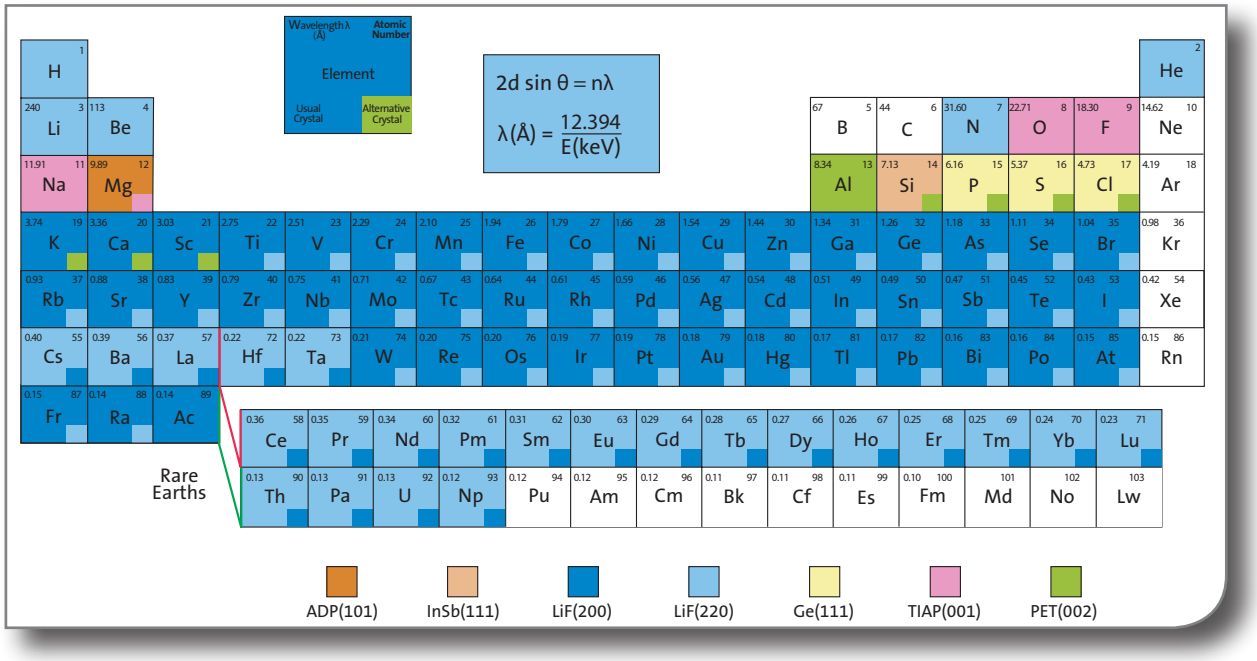
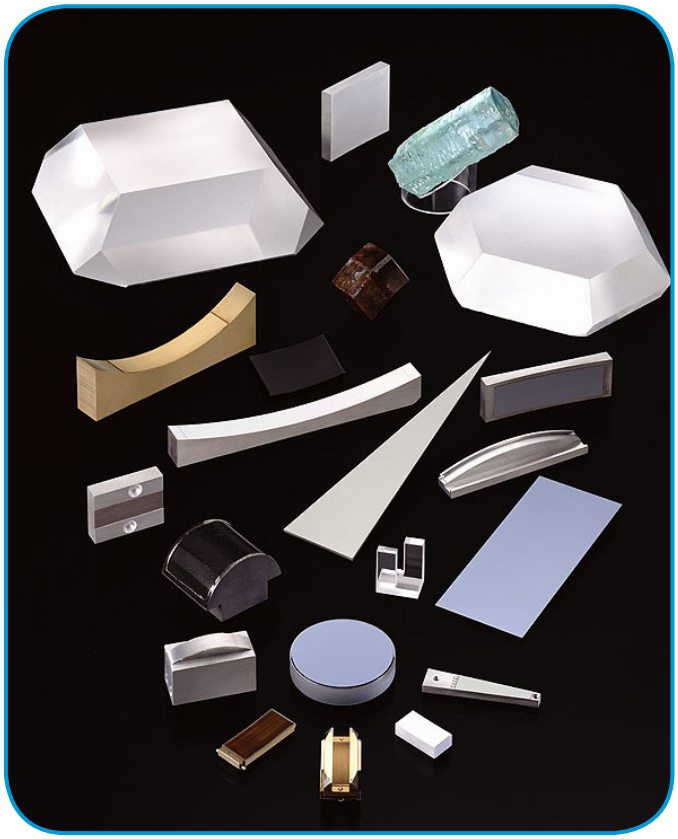
Catalogue of Saint-Gobain Crystals monochromators

Crystal	*Lithium fluoride* (1)			*Quartz*		*Indium Antimonide*	*Silicon*		*Germanium*	
				(1)	(2)		(1)	(2)	(1)	(2)
Chemical formula	LiF			SiO_2		InSb	Si		Ge	
Crystal system	Cubic			Hexagonal (3)		Cubic	Cubic		Cubic	
Parameters:										
a.....Å....	4.027			4.913		6.48	5.431		5.658	
b.....Å....				4.913						
c.....Å....				5.405						
β.....										
Reflecting planes orientations	(200)	(220)	(420)	(1011)	(1010)	(111)	(111)	(220)	(111)	(220)
2d in Å	4.027	2.848	1.801	6.684	8.514	7.480	6.271	3.840	6.532	4.000
Usual surface finish	Cleaved or Treated	Treated	Treated	Polished	Polished	Polished	Polished	Polished	Polished	Polished
Reflectivity	Intense	Intense	Average	Good	Good	Intense	Intense	Average	Intense	Intense
Calibration elements	Mo, Fe, Ti	Mo, Fe	Mo	Cu	Cu	Si	Cu	Cu	Cu	Cu
Common applications	From K to heavy elements	Heavy elements Lines splitting	Heavy elements Lines splitting	As Ge (111)	As PET	Quantitative analysis of silicon	Extinction of even order spectral lines			

Crystal	*Pentaerythritol PET*	*Ammonium Dihydrogen Phosphate ADP*	*Beryl (2)*	*Acid Phthalates*			
				Thallium TlAP	*Rubidium RbAP*	*Potassium KAP*	*Cesium CsAP*
Chemical formula	$C(CH_2OH)_4$	$NH_4H_2PO_4$	$3BeO,Al_2O_3$ $6SiO_2$	$CO_2HC_6H_4CO_2Tl$	$CO_2HC_6H_4CO_2Rb$	$CO_2HC_6H_4CO_2K$	$CO_2HC_6H_4CO_2Cs$
Crystal system	Quadratic	Quadratic	Hexagonal	Orthorhombic	Orthorhombic	Orthorhombic	Orthorhombic
Parameters:							
a.....Å....	6.16	7.530	9.21	6.63	6.55	6.46	6.580
b.....Å....	6.16	7.530	9.21	10.54	10.02	9.61	10.752
c.....Å....	8.74	7.542	9.17	12.95	13.06	13.33	12.825
β.....							
Reflecting planes orientations	(002)	(101)	(1010)	(001)	(001)	(001)	(001)
2d in Å	8.740	10.648	15.950	25.900	26.120	26.640	26.650
Usual surface finish	Cleaved or treated	Polished or treated	Polished	Cleaved	Cleaved	Cleaved	Cleaved
Reflectivity	Intense	Average	Average	Intense	Intense	Good	Good
Calibration elements	Al, Si	Mg	Mg	Na, Mg	Na	Na	Na
Common applications		Mg	Na and following elements	F to Al	Na to Al, up to F in emission probes	Na to Al, up to F in emission probes	Na to Al, up to F emission probes

(1) Other cuts can be supplied upon request.
(2) Noteworthy for its high radiation damage threshold (synchrotron).
(3) The quartz unit cell is rhomboedric. The parameters given here correspond to a multiple hexagonal cell, defined as for beryl by a = b≠c α= β = 90° y= 120°


Wavelength λ (Å)
Atomic Number
Element
Usual Crystal
Alternative Crystal
2d sin θ = nλ
λ(Å) = 12.394 / E(keV)
H 1
He 2
Li 3 240
Be 4 113
B 5 67
C 6 44
N 7 31.60
O 8 22.71
F 9 18.30
Ne 10 14.62
Na 11 11.91
Mg 12 9.89
Al 13 8.34
Si 14 7.13
P 15 6.16
S 16 5.37
Cl 17 4.73
Ar 18 4.19
K 19 3.74
Ca 20 3.36
Sc 21 3.03
Ti 22 2.75
V 23 2.51
Cr 24 2.29
Mn 25 2.10
Fe 26 1.94
Co 27 1.79
Ni 28 1.66
Cu 29 1.54
Zn 30 1.44
Ga 31 1.34
Ge 32 1.26
As 33 1.18
Se 34 1.11
Br 35 1.04
Kr 36 0.98
Rb 37 0.93
Sr 38 0.88
Y 39 0.83
Zr 40 0.79
Nb 41 0.75
Mo 42 0.71
Tc 43 0.67
Ru 44 0.64
Rh 45 0.61
Pd 46 0.59
Ag 47 0.56
Cd 48 0.54
In 49 0.51
Sn 50 0.49
Sb 51 0.47
Te 52 0.45
I 53 0.43
Xe 54 0.42
Cs 55 0.40
Ba 56 0.39
La 57 0.37
Hf 72 0.22
Ta 73 0.22
W 74 0.21
Re 75 0.20
Os 76 0.20
Ir 77 0.19
Pt 78 0.19
Au 79 0.18
Hg 80 0.18
Tl 81 0.17
Pb 82 0.17
Bi 83 0.16
Po 84 0.16
At 85 0.15
Rn 86 0.15
Fr 87 0.15
Ra 88 0.14
Ac 89 0.14
Rare Earths
Ce 58 0.36
Pr 59 0.35
Nd 60 0.34
Pm 61 0.32
Sm 62 0.31
Eu 63 0.30
Gd 64 0.29
Tb 65 0.28
Dy 66 0.27
Ho 67 0.26
Er 68 0.25
Tm 69 0.25
Yb 70 0.24
Lu 71 0.23
Th 90 0.13
Pa 91 0.13
U 92 0.13
Np 93 0.12
Pu 94 0.12
Am 95 0.12
Cm 96 0.12
Bk 97 0.11
Cf 98 0.11
Es 99 0.11
Fm 100 0.10
Md 101
No 102
Lw 103
ADP(101)
InSb(111)
LiF(200)
LiF(220)
Ge(111)
TlAP(001)
PET(002)

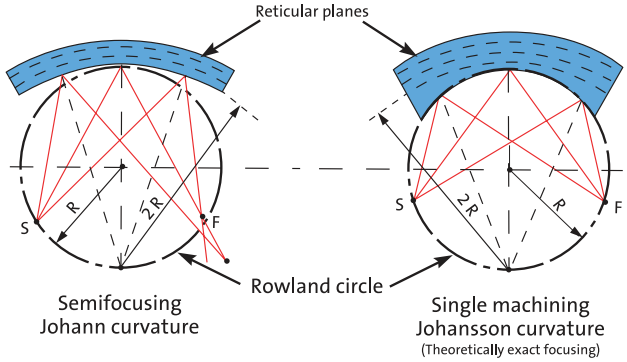


Crystals for X-Ray Spectrometry

The Johann geometry

A thin plate, produced by one of the two following methods:

- Cleavage for LiF (200)-PET-TIAP-RbAP-KAP
- Machining for other materials, is further cylindrically curved and glued upon a holder of curvature radius 2R. It is possible to show that a beam emitted by a source at S is approximately focused at F. The source and focus are both located on the so-called Rowland circle whose radius is R

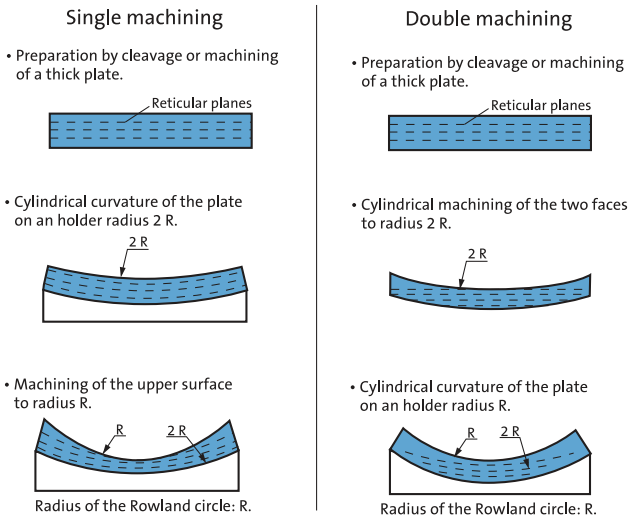


The Johansson geometry

Two different types of Johansson configurations, theoretically leading to perfect focusing, are considered:

- Single machining Johansson
- Double machining Johansson

The illustrations represent the fabrication steps of Johansson plates in both techniques.



Johansson curvatures

Saint-Gobain Crystals will choose the most appropriate technique according to the type of crystal, its dimensions and the radius of Rowland circle to be achieved.

The orientation accuracy is better than 10 minutes, except for the Johann cleaved configuration, where it is 1 minute.

Other types of curvature may be investigated on request. For example, curvatures on holders shaped as logarithmic spiral, elliptic, parabolic, even spheric designs, interesting in plasma or synchrotron radiation study and astrophysics.

Manufacturing capabilities will strongly depend upon the crystal nature and dimensions as well as on the curvature radii.

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Manufacturer reserves the right to alter specifications.