CRL SYSTEMS
FOR SYNCHROTRONS AND FELs

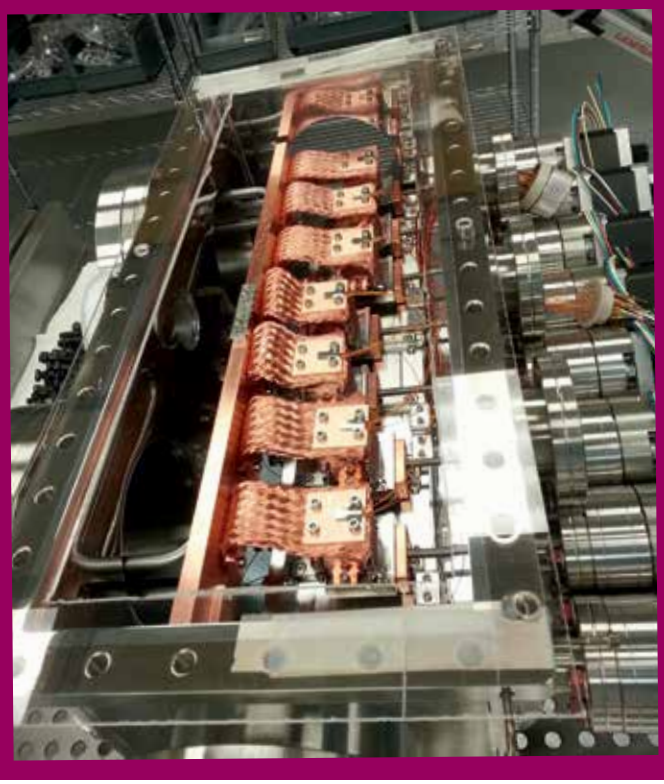
JJ X-RAY

Danish Science Design

REFRACTIVE OPTICS

Compound Refractive Lens Systems (CRL systems or transfocators) are used as collimating or focusing elements in x-ray beamlines on FEL´s and synchrotrons.

The first JJ-Xray system was installed in 2006 and the technology have matured steadily since then. Today we have systems in operation at 9 different synchrotrons and FEL´s: APS, NSLS-II, SSRF, ESRF, LCLS, European-XFEL, CAMD, SSRF and NSRRC



KEY FEATURES

- Beam stability - significantly less sensitive to vibrations than for instance mirror focusing.
- Highly insensitive to surface contaminations e.g. carbon depositions.
- Fast to reach thermal stability due to low thermal mass.
- Well suited for white beam applications.
- Compact design, down to 15 cm.
- Single- or tunable energy setup.
- The systems are generally modular in design and can be scaled relatively freely.
- Designs for UHV, HV and in-air operation are available

ALIGNMENT

CRL systems are typically delivered with a five-way transfocator system offering; pitch, yaw, lateral, vertical and longitudinal motion of the CRL vessel. The freedoms of a transfocator system makes it straight forward to optimize the alignment of the lenses during normal use and the initial commissioning typically lasts no more than a day to complete. The longitudinal motion is generally in the range of 60cm and enables the CRL to be used over a continuous energy range as the P:Q values can be tuned to match a changing X-Ray energy.

OVERALL CATEGORIES

- OVER 3W DEPOSITED PER LENS: WATER COOLED - FOR WHITE OR PINK BEAMS.
- BETWEEN 0.5W AND 3W DEPOSITED PER LENS: BRAID COOLED - FOR PINK OR MULTILAYER-MONOCHROMATIC BEAMS.
- BELOW 0.5W DEPOSITED PER LENS: UNCOOLED - FOR MONOCHROMATIC BEAMS.

BEAM STABILITY

A key feature of CRL focusing is that it is significantly less sensitive to vibrations than for instance mirror focusing: The moment transfer of a reflective mirror and a refractive CRL is given as below, where k is the is the wave vector, ϑ is the incidence angle (or angular vibration), N is the number of lenses (typically between 10 and 100 lenses are used) and δ is the real part of refractive index (which is material and energy dependent number, but typically it is in the order of 10^{-6}):

Mirror $Q = 2k \sin \vartheta$

CRL $Q = N½ \, k \, \delta$

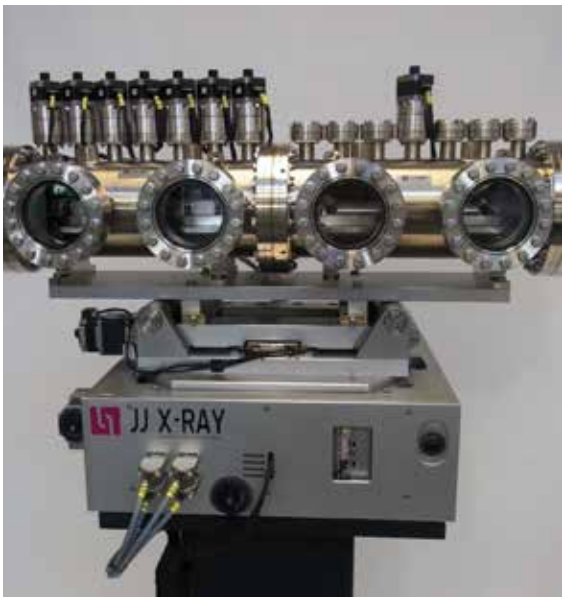
By this, it can be deduced that lenses are in the order of at least for all practical purposes, 100 times less sensitive to vibrations. The same principle can be applied to surface contaminations, so CRL´s are basically insensitive to for instance carbon depositions.

See J. Synchrotron Rad. (1999) 6, 1153-1167 for further details.

THE LENSES

A CRL system is typically used on a hard x-ray line with the lens material being Be, Al or Ni as the energy increases. Since autumn 2019, lenses of single crystal diamond material have been available as well. The refractive lenses can either be shaped as a rotated parabola and focus in 2D, or as a cylindrical parabola, and focus in 1D.

- Beryllium Lenses (2-40 keV)
- Aluminium Lenses (40-80 keV)
- Nickel Lenses (80–150 keV)
- Single crystal Diamond (5-90 keV)

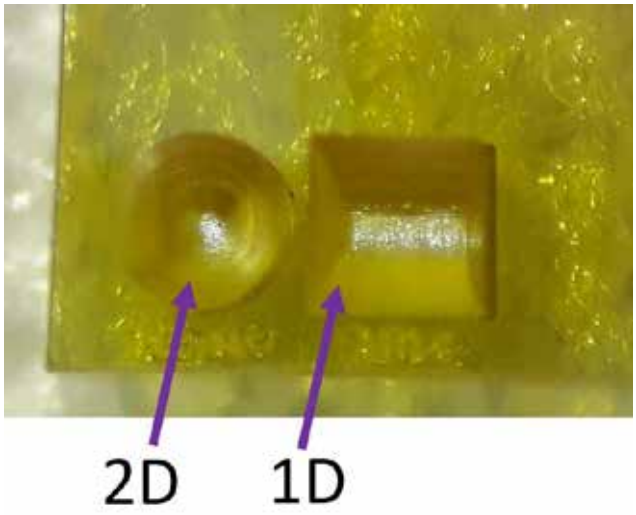


SINGLE CRYSTAL DIAMOND CRLs

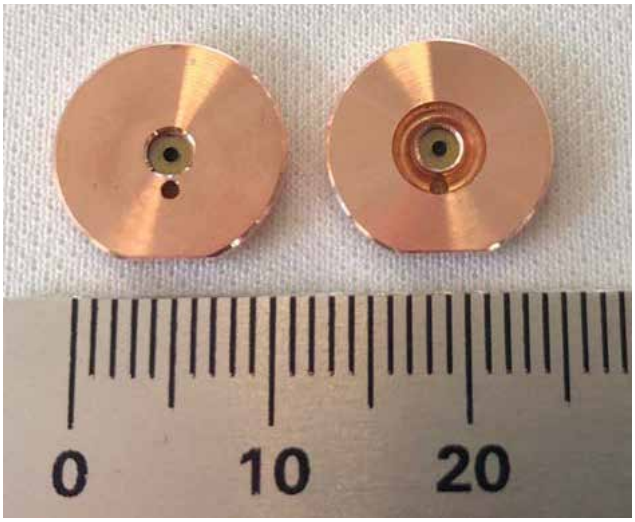
JJ X-Ray and the Danish Technical University have over the last two years been developing Compound Refractive Lenses (CRL) of Single Crystal Diamonds (SCD´s) and will continue the development in the foreseeable future.

The shape of the lens can be made relatively freely and thus be tailored to the parameters of the specific beamline, they will be deployed for. It is also possible to make more lenses in one diamond, e.g. a 2D and a 1D lens can be positioned next to each other.

More information is available on www.jjxray.dk



2D CRL and 1D CRL using the same lens casette.



Cu disks fitted with SCD CRL´s.

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