X-Ray Diffraction

X-ray diffraction is a widely used technique that evaluates angular distribution of X-rays coming from the sample. If the sample is other than a single crystal, e.g., a powder sample, a highly parallel beam is needed for irradiating the sample. Under certain conditions, a single crystal sample a convergent beam may be used.

Because angular distribution of the X-rays is being sought, it is not generally useful to use a Kumakhov lens which collects divergent rays from the sample and forms a parallel beam or forms a convergent beam. As shown in FIGS. **14A** and **14B**, an important benefit is the use of a Kumakhov lens **182**, **188** between the source **180**, **186** and sample **184**, **190** to fashion a beam which is parallel or convergent, as required for the particular analysis of a desired cross-sectional size and shape. Also useful is the ability to selectively filter out undesirable photon energies prior to the X-rays striking the sample by use of lens manufacture combinations, designing the Kumakhov lens channels to be bent in such a shape that they filter out higher energies, using materials which absorb lower energies, or using Kumakhov lenses which provide tailored band widths.

A Kumakhov lens **192** can also be used to collect parallel X-rays from the sample **190** and focus those photons on the detector **194**. This configuration is very selective for a narrow angular range of X-rays coming from the sample **190** without the losses inherent in normal collimation and only requiring a small detector **194**.

Neutron Diffraction

The same geometries discussed for X-ray diffraction work for neutron diffraction, including filtering to control the energy band width. However, to use Kumakhov lenses for neutrons it is necessary to construct the lenses or coat the lenses with materials which have a very low absorption of neutrons. For example, materials containing boron are unsuitable because of boron's high absorption cross-section for neutrons.

Upon reading the above specification, variations and alternative embodiments will become obvious to one skilled in the art and are to be considered within the scope and spirit of the subject invention. The subject invention is only to be limited by the claims which follow and their equivalents.

What is claimed is:

1. An analytical instrument for analyzing a sample by means of analysis radiation, the analysis radiation being selected from the group consisting of x-ray radiation, gamma-ray radiation, neutron-beam radiation, and ion-beam radiation, the instrument comprising:

(a) a radiation source adapted to produce source analysis radiation, the source analysis radiation selected from the group consisting of x-ray radiation, gamma-ray radiation, neutron-beam radiation, and ion-beam radiation;

(b) sample-positioning means for positioning a sample in a sample-irradiation position for irradiating the sample with analysis radiation from the source analysis radiation produced by the radiation source;

(c) a radiation detector for detecting analysis radiation from the sample, an instrument radiation path being defined from the radiation source to the radiation detector, the sample-irradiation position being located in the radiation path at a position intermediate between the radiation source and the radiation detector; and

(d) a multiple-channel, multiple-total-external-reflection lens positioned in the instrument radiation path at a radiation-reorientation position, the multiple-channel, multiple-total-external-reflection lens including at least one polycapillary-bundle element, each polycapillary-bundle element being a substantially unitary structure having a plurality of passageways extending through the polycapillary bundle element in a generally longitudinal direction to define a plurality of capillary-channel passageways, each capillary-channel passageway having substantially smooth inner-surface portions capable of providing total external reflection of analysis radiation incident upon the surface portions at an angle below a critical angle of total external reflection for radiation of the energy of the analysis radiation, each capillary-channel passageway having a longitudinal axis defined extending longitudinally through the capillary channel passageway, each polycapillary-bundle element having an input radiation-capture face and an output radiation-emission face, each capillary-channel passageway of the polycapillary-bundle element opening at a first end through the input radiation-capture face of the polycapillary-bundle element to define a radiation-capture input opening of the passageway, each capillary-channel passageway of the polycapillary-bundle element opening at a second end through the output radiation-emission face of the polycapillary-bundle element to define a radiation-emission output opening of the passageway, each polycapillary-bundle element being shaped so that the longitudinal axis of each of the capillary channel passageways of the element polycapillary bundle extend substantially parallel to a curvilinear path which defines a multiple-reflection total-external-reflection path associated with the passageway, the multiple-reflection total-external-reflection path being defined so that for each capillary-channel passageway analysis radiation incident upon the radiation-capture input opening of the capillary-channel passageway propagating in a direction sufficiently close to the direction of the longitudinal axis of the passageway at the radiation-capture input opening can be channeled through the passageway in a series of reflections by total external reflection from inner wall surfaces of the passageway, the number of such reflections by total external reflection for each passageway being generally greater than two, each polycapillary-bundle element of the multiple-channel, multiple-total-external-reflection lens being shaped to capture at the respective input radiation-capture face, reorient, and emit from the output-emission face analysis radiation so that the multiple-channel, multiple-total-external-reflecting lens captures, reorients, and emits analysis radiation in the radiation path of the analytical instrument.

2. The analytical instrument of claim **1** in which the multiple-channel, multiple-total-external-reflection lens is located in the instrument radiation path at a position intermediate of the radiation source and the sample-irradiation position.

3. The analytical instrument according to claim **2** in which each of the at least one polycapillary-bundle element of the multiple-channel, multiple-total-external-reflection lens is shaped so that the lens is a divergent beam concentrator.

4. The analytical instrument of claim **3** in which the polycapillary-bundle elements of the multiple-channel, multiple-total-external-reflection lens are shaped so that the lens has an input radiation-capture focal point associated with the