LAYOUT OF ULTRAHIGH-VACUUM DOUBLE-CRYSTAL MONOCHROMATOR

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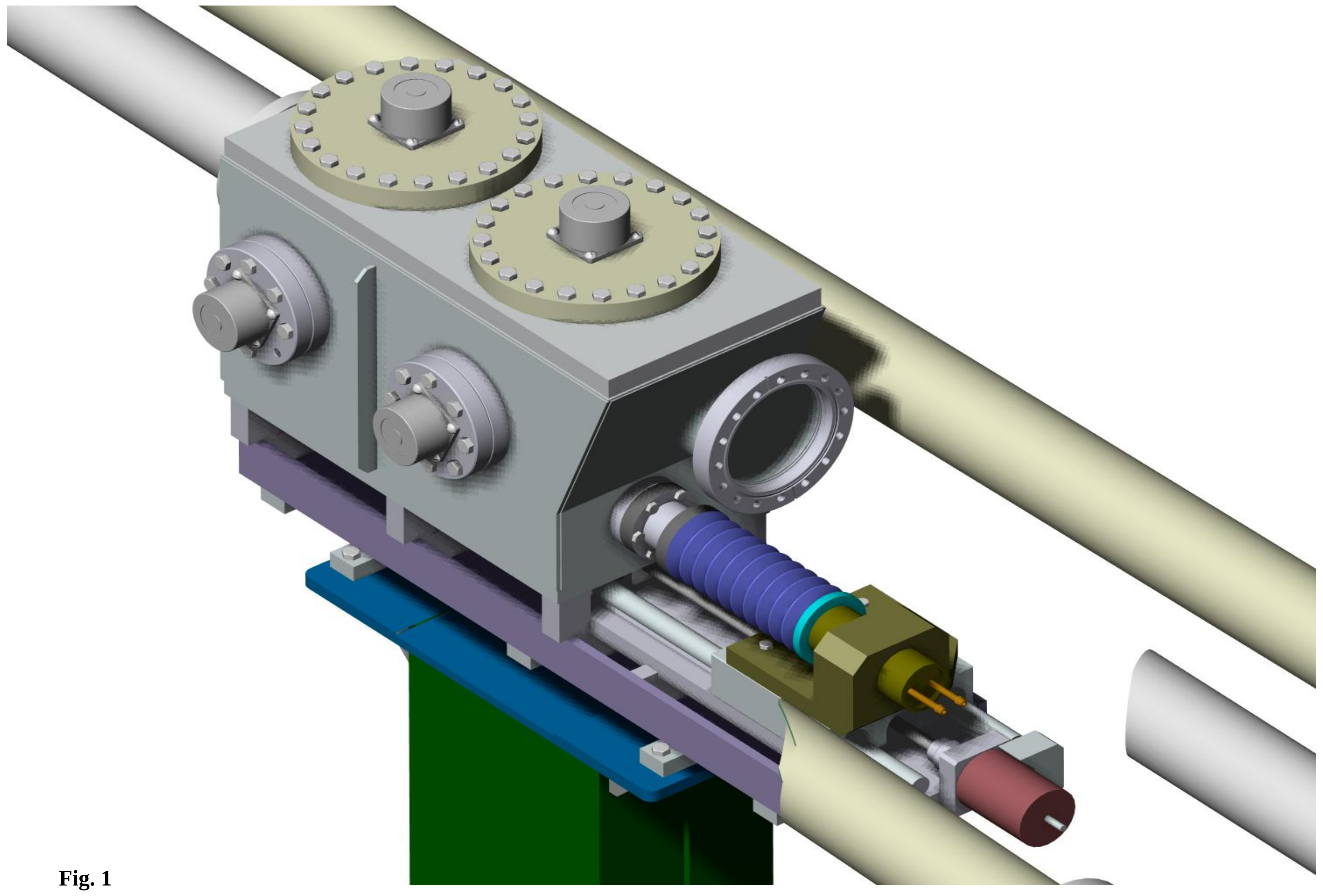

Fig. 1

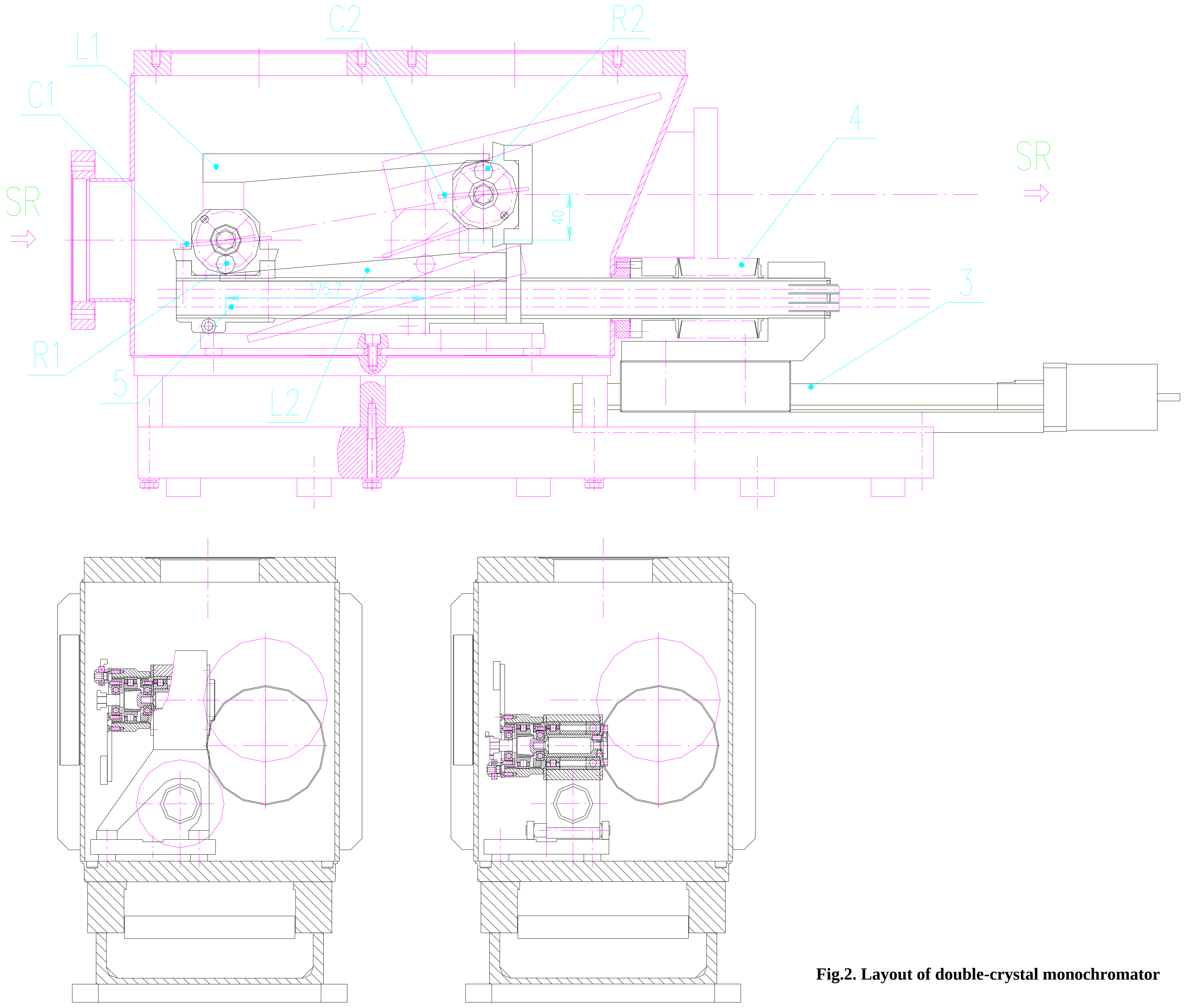

Fig.2. Layout of double-crystal monochromator

Design features of this monochromator

Developed monochromator, which can work at ultrahigh vacuum, is planned to establish on 6-th SR beam-line of the storage ring VEPP-3. Its general view and prospective arrangement concerning the neighbouring beam-lines can be seen in a Fig. 1.

More detailed layout of a design of double-crystal monochromator is shown in a Fig. 2; this layout is development of our earlier project [1]. In the scheme [1], the important element of a design were the copying rulers having a complex profile line, which determined turn of levers and crystals. In given, new variant of the kinematics, the crystal's levers are supported by rollers (which position is fixed concerning axes of rotation of the appropriate crystals). It is possible to find such variant of configuration, position of rollers and levers, at which the working surface of levers can be "simple" – simply plane.

Thus, the overall objective achievable in the given variant is that the most crucial surfaces of elements of construction are "simple", i.e., plane or surface of the cylinder, that allows to achieve higher accuracy at their manufacturing.

The movement of the first crystal C1 (and all unit of a crystal C1) is made by a horizontal stage 3 (with a working range of ~190 mm; Huber stage) through bellows 4 with the help of a plunger-rod 5 (see fig. 2). Inside a rod, there are provided two tubes for water cooling of the first crystal. The change of height of a beam determined by a vertical position of the second crystal, is h=40 mm, and the range of energy at work with crystals Si 111 makes 5–19 keV.

The axis of rotation of the second crystal C2 is fixed, and the turn of this crystal develops of two parts. The first part is a rather fast turn with the help of the lever L2 clamping to a roller R1. The accuracy of manufacturing and assembly of elements of the mechanics guarantees correct absolute orientation of crystals with an error ~10''(in the middle of a working range). This error is increased for the large theta-angles and low energies, but thus width of a rocking curve of crystals grows as well. The precise tuning of theta-angle (pitch-angle) of the second crystal is provided with the help of the mechanism using tense wave friction transfer (harmonic drive) with high transmission factor, which changes the angle between the lever and the crystal plane with a step ~0.1''; this mechanism is discussed in separate poster.

The similar unit of fine tuning is present also for an axis of the first crystal, but it is used only for preliminary monochromator set-up (tuning of the angle φ1 between planes of the lever L1 and crystal C1), required after replacement of crystals.

Calculation of optimum parameters of a kinematic configuration

Let's consider at first problem of calculation of an precise profile of the lever (necessary for a fixed_exit condition) in approximation of a dot roller - correction on radius of a roller does not make problems. The origin in a Fig. 3 (for axes u, v) is the axis of rotation of the first crystal, A1; the axis u goes to in parallel crystal planes. The axis of the second crystal, A2, is visible under angle ϑ to an axis u and is away from A1 on distance $L = h / \sin 2\vartheta$. The parameters a and b determine position of a roller R2, which support the lever L1. For roller R2 co-ordinates (u, v) it is easy to find the following expressions (angle ϑ varies in a range 5°–19°; $L = h / \sin 2\vartheta$):

$$u(\vartheta) = (L + a)\cos\vartheta + b\sin\vartheta;\quad v(\vartheta) = (L - a)\sin\vartheta + b\cos\vartheta.$$

In the Fig. 4, the profile of the lever, $v(u) - v_0$ ($v_0 = h/2 + b$), calculated for a number of option values b are submitted, at a = 0. For a case b = 21.5, profile with high accuracy (tens micron) is approximated by a straight line.

Now we shall consider the other problem: for a case of the flat lever it is necessary to find deviations of height of an output beam

$$\Delta h(x) = h^* - h \text{ (where } x = x_{A2} - x_{A1} = -x_{A1} \text{ – "control" parameter)}$$

in a working range. Parameters of the lever are: B – offset of a plane of the lever concerning an axis A1, φ – angle between a plane of the lever and crystal planes, see a fig. 5. For an angle α it is possible to obtain the equations:

$$(x + a)\sin\alpha + B = (h + b)\cos\alpha,\quad \alpha = \vartheta + \varphi.$$

That is, the function $x(\vartheta)$ is found. Now we find distance between planes of two crystals, D, and also h^*:

$$D = h\cos\vartheta - x\sin\vartheta,\quad h^* = 2D\cos\vartheta.$$

In a result we obtain dependence (or function) $h^*(x)$ in a parametric form:

$$x(\vartheta) = (h + b) / \tan(\vartheta + \varphi) - B / \sin(\vartheta + \varphi) - a,$$
$$h^*(\vartheta) = 2(h\cos\vartheta - x\sin\vartheta)\cos\vartheta.$$

In a Fig. 6 the dependences $\Delta h(x)$ are shown, calculated for a number of values of parameters, including for optimum, on our sight, variant:

$$a = 0;\ b = 21.5;\ B = 41.5;\ \varphi = 0.4\text{ '' (at } h = 40).$$

It is possible to receive more complete result taking into account deflection of the second crystal at sagittal focusing (and also displacement of crystals from axes of turn). In this case, optimum parameters differs a little (~ 0.5 mm).

The closing remarks

The given design of a double-crystal monochromator allows to have a minimum of tunings at its work; the high accuracy of manufacturing of the most important monochromator elements allows to lower time necessary for energy tuning. Thus an optimum choice of parameters of a design (the position of rollers and levers) allows to reduce variations of height of a output beam (on all working range of energy) up to enough low level: Δh ~ 10 microns.

All elements of a design sustain warming up at 300°C and can work in ultrahigh vacuum; very small monochromator width – only 250 mm – allows to establish it on 6-th SR beam-line in a narrow free space limited to the neighbouring beam-lines.

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[1] A.I. Ancharov, N.G. Gavrilov et al, Nucl. Instr. and Meth. A 470 (2001) 128.

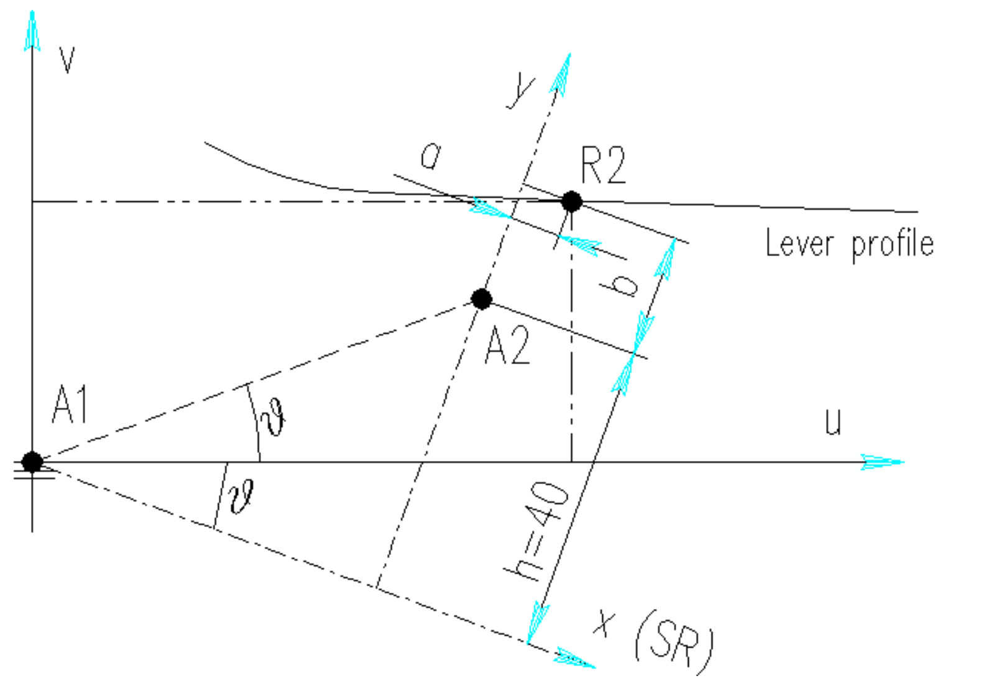

Fig.3. Derivation of exact lever profile for "fixed exit"

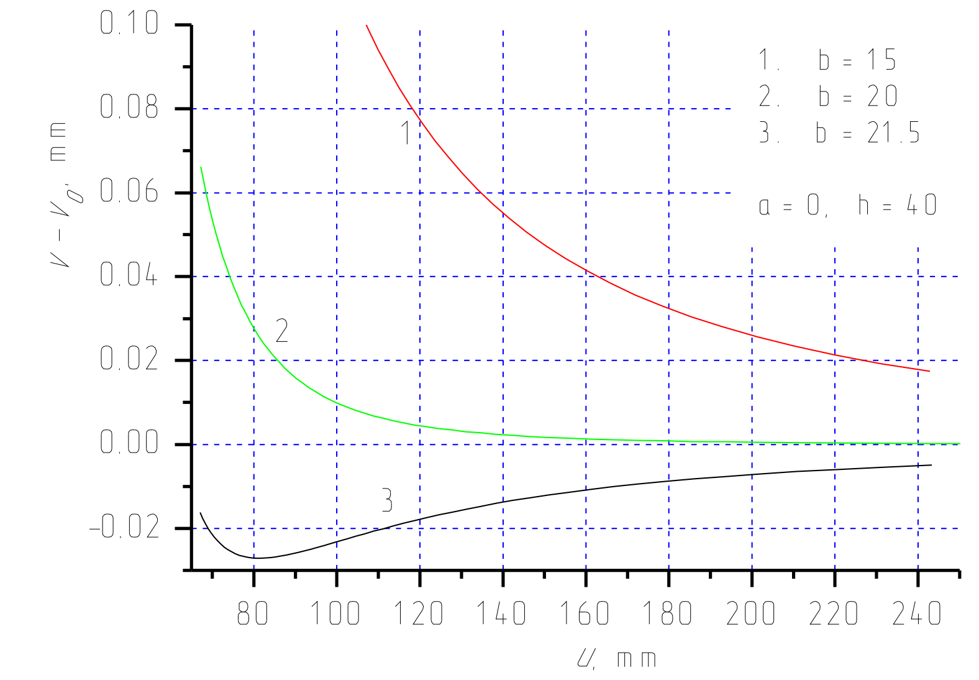

Fig.4. Lever profiles (fixed exit condition) calculated for different parameters.

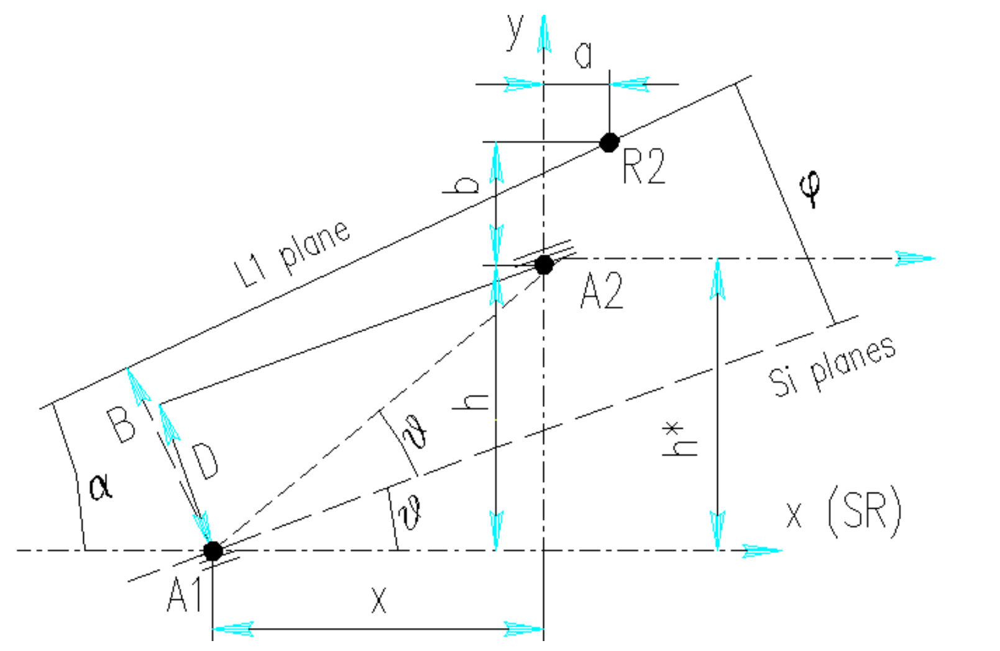

Fig.5. Derivation of output beam height *h*(x)* (plane lever)

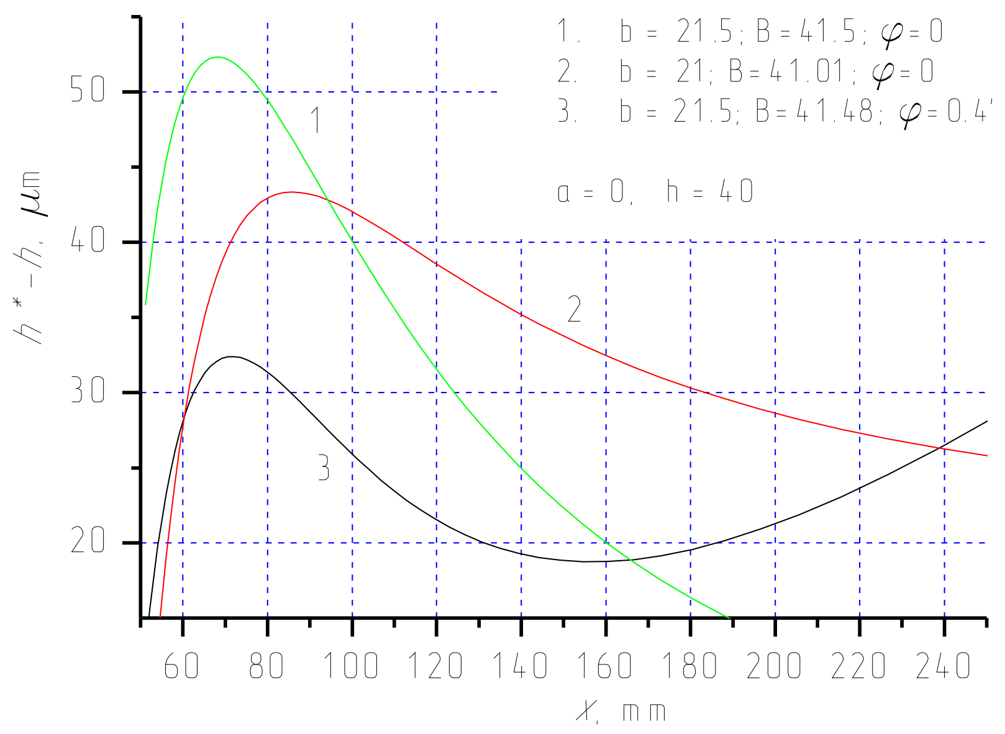

Fig.6. Deviations of output beam height *h*(x)*.