

APPENDIX C

Cubic Crystal Tilt Requirements

If it were possible to set the minute tilt angle so that the minute offset of $3 \cdot 10^{-19}$ meter as called for by the Section 4 development could be precisely set and maintained, the “fundamental case”, such that the first lattice layer offset is that amount and successive multiples of it sequentially are in the successive layers [2nd layer offset is twice the initial layer; 3rd layer offset is thrice the initial layer; etc.], that direct approach would be taken.

However, the setting of such a minute angle and offset, much less doing so sufficiently precisely, is not practical and probably impossible. To operate using a larger and less precise tilt angle, any tilt angle, the same sufficient number of layers overall required for that “fundamental case” must be employed and the tilt must be such that the actual *x-axis offset* and the actual *y-axis offset* are such that, after that “same sufficient number of layers overall”, each required atomic position appears somewhere, in some layer, even though not necessarily in “sequential order”.

THE EXACT SUBMULTIPLE OF INTERATOMIC SPACING ISSUE

The most obvious condition of tilt angle and offset that would interfere with “each required effect appearing somewhere, in some layer” would be the actual *offsets* being an exact sub-multiple of the actual interatomic spacing.

For example: with a tilt angle tangent of 0.01 , a tilt angle of 0.57° , the layer-to-layer offset would be 0.01 of an interatomic spacing. Layer #2 would be offset $0.01 \times (2.7 \cdot 10^{-10}) = 2.7 \cdot 10^{-12}$ meter from layer #1, layer #3 the same from layer #2 ..., and layer #101 would be offset a total of $2.7 \cdot 10^{-10}$ meter, the actual interatomic spacing, from layer #1.

In that circumstance any further layers would only reproduce

the atom locations relative to the vertical U-wave flux that the first 100 layers had introduced.

But if the layer-to-layer offset were such that by layer #101 they accumulated an additional $3 \cdot 10^{-19}$ meter total offset from layer #1, then the second 100 layers would deliver atoms all spaced that $3 \cdot 10^{-19}$ meter beyond the atoms of the corresponding layers of the first 100 and the third 100 layers would be correspondingly offset from the second, and so on to ultimately delivering an atom in each of $3 \cdot 10^9$ intervals in each $2.7 \cdot 10^{-10}$ meter interatomic space horizontally in the crystal.

If that “additional $3 \cdot 10^{-19}$ meter total offset” were, instead, any integer multiple of that amount [but still much less than the $2.7 \cdot 10^{-10}$ actual interatomic spacing] the same overall result would obtain – the in effect shuffling of the layers of the cubic crystal lattice.

The actual *offsets* not being an exact sub-multiple of the actual interatomic spacing is essentially automatically assured. The inverse, requiring a perfect integral sub-multiple relationship would be essentially impossible in practice. That is determined as follows.

A rational number is a number that can be expressed as the ratio of two integers. A rational number expressed as a decimal fraction always exhibits a repetition, over and over, of the sequence of digits in its expression, for example: $0.33333333 \dots = 1/3$ or $0.125125125 = 1/8$. Conversion of a repeating decimal fraction to the ratio of two integers is done as in equation (C-1) on the following page.

Any number exhibiting such a repeating sequence is rational. Any number that does not exhibit such a repeating sequence is not rational, cannot be converted per equation (C-1), above, and is therefore irrational.

Consequently, while the number of rational numbers in any interval is finite, the number of irrational numbers in any interval is infinite.

- (C-1) [a] The fraction is defined as "F".
 a, b, c, ... are digits from the set:
 0, 1, ... 9
 $F = 0.abcd \dots abcd \dots abcd \dots$
- [b] Where n = number of digits in F then
 $10^n \cdot F = abcd \dots \cdot abcd \dots abcd \dots abcd \dots$
- [c] Then, using $n = 4$ as an example:
 $10^4 \cdot F - F = abcd$
 $9999 \cdot F = abcd$
- [d] $F = abcd / 9999$

Now consider set N , a set of n integers [n finite]: 1, 2, 3, ... , n . That set is finite, has a finite number of members, is countable and enumerable. Now consider set R , all rational numbers such that each such number has a member of N as its numerator and a member of N as its denominator. There are n members of N . There are n^2 members of R . The number of members of N and of R is finite.

Now consider set I , all irrational numbers greater than zero and less than n . The number of members of set I is infinite. Therefore, the random selection of any number in the interval zero to n , has an infinite probability of being irrational and an infinitesimal chance of being rational.

Therefore, for any installed tilt angle and the offset that it produces, the chance that it would be an exact sub-multiple of the actual interatomic spacing is nil.

On the other hand, the chance that some particular achieved tilt angle and offset requires more layers of cubic crystal than the "fundamental case" because of inefficient scheduling of successive positions is a significant consideration.

TEMPERATURE VARIATION

In addition, a number of variable natural effects are much greater than the precise offset of $3 \cdot 10^{-19}$ meter. The effects of temperature variation in the Silicon cubic crystal and various random vibrations within it would overwhelm such a minute setting.

Most materials tend to expand with increase in their temperature. The measure of that effect is the Thermal Coefficient of Expansion, α . That coefficient relates to thermal expansion of the material as in equation (C-2).

$$(C-2) \Delta L = \alpha \cdot L \cdot \Delta T$$

where:

ΔT = change in temperature in degrees centigrade*

L = length of a dimension of the material

ΔL = change in L due to ΔT

α = thermal coefficient

For Silicon $\alpha = 3 \cdot 10^{-6}$ per degree Kelvin*
at 20° Centigrade

For the interatomic spacing of Silicon the effect of temperature change is per equation (C-3), below.

$$\begin{aligned} (C-3) \Delta L &= \alpha \cdot L \cdot \Delta T \\ &= [3 \cdot 10^{-6}] \times [2.7 \cdot 10^{-10}] \\ &= 8 \cdot 10^{-16} \text{ meters per degree Kelvin} \end{aligned}$$

* The Kelvin temperature scale has its “zero”, i.e. begins at, absolute zero, the lowest possible temperature. The Centigrade [Celsius] temperature scale has its “zero” at 273.15° Kelvin, i.e. they are offset by 273.15°. The magnitude of changes in the two scales are identical; a change of 1° Centigrade = a change of 1° Kelvin.

That as compared to the offset of $3 \cdot 10^{-19}$ meter to be created by the tilt. The one-degree temperature variation is over 2,600 times the objective offset. Even a $1/1000$ degree temperature variation is over double the objective offset. For that reason alone, the setting and maintaining of so precise an objective offset is impractical.

The thermal coefficient of Silicon itself varies with temperature. More precisely it ranges from 2.6 to 3.3 [$\times 10^{-6}$] over the temperature range of 20° to 100° C.

THERMAL VIBRATIONS AND BLACK BODY RADIATION

The Silicon crystal, at more or less room temperature and as most other materials at that energy, continuously radiates heat energy at frequencies in the infrared range. [The wavelength of infrared radiation is in the range of $3 \cdot 10^{-4}$ to $3 \cdot 10^{-7}$ meters, its frequency being in the range of 10^{12} to 10^{15} Hz [cycles per second].] The crystal also simultaneously absorbs the same kind of radiation from other objects. Its atoms are continuously oscillating, vibrating. Such radiation of that energy comes from a reduction in some atoms' oscillations and such absorption is to an increase in some atoms' vibrations.

If the crystal's temperature is greater than its surroundings its radiated energy exceeds that absorbed and it cools down toward thermal equilibrium with its surroundings. Conversely, if it is cooler than its surroundings its temperature increases due to its absorbing more energy than it radiates.

The heat energy corresponding to the crystals' temperature exists in the crystal as the vibratory oscillations of its atoms about their neutral [temperature = 0° Kelvin] position. In a crystal lattice the atoms are bound to their average positions by the neighboring atoms. The spectrum of lattice vibrations ranges from low frequencies to ones on the order of 10^{13} Hz.

The dependency of atoms' vibrations on its neighbors depends on temperature. At room temperature range most of the thermal energy is in the vibrations of highest frequency. Because of the short corresponding wavelength the motion of neighboring atoms is essentially uncorrelated so that the vibrations can be considered as independently vibrating atoms, each moving about its average position in three dimensions.

[At high temperature they are not independent of each other. At higher temperatures, not applicable to the present analysis the adjacent atoms are more interrelated in their motions and result in oscillatory waves in the crystal lattice.]

The thermal expansion with increase in temperature is due to the increased amount of energy [heat] in the crystal, and the consequent increase in the amplitude of the crystal's vibrations. The above calculated change in length in Silicon per degree centigrade is the change in amplitude of the atom's vibration.

The ΔL per degree K [= degree C] of $8 \cdot 10^{-16}$ meters per interatomic space of equation (C-2) is about 1 part in $3 \cdot 10^5$ of the interatomic space. Being the amplitude change that occurs per degree in a range of 100 or more degrees that implies a larger overall amplitude of on the order of 100 or more times that, $8 \cdot 10^{-14}$ meters, or about 0.0003 of the interatomic spacing.

The overall net effect of this is that atomic locations and interatomic spacings are continuously shifting and varying in oscillatory fashion. The amplitude of these shifts is only a small fraction of the interatomic spacing of $2.7 \cdot 10^{-10}$ meters.

On the other hand the amplitude of those shifts is on the order of over 250,000 times the $3 \cdot 10^{-19}$ meter objective distance from an atom that is sought to be achieved. That is, the lattice thermal vibrations cause the atoms to oscillate back and forth about their nominal neutral position a distance on the order of over 250,000 times the $3 \cdot 10^{-19}$ meter objective distance from an atom that it is

sought to cause all of the Earth's gravitational field to pass in some layer of the crystal.

That $8 \cdot 10^{-14}$ meters oscillatory atomic location range covers over 250,000 desirable or suitable objective atomic locations each one of which is effectively randomly sampled or occupied by the thermal vibrations along with all of the others.

THE RANDOM DISTRIBUTION SOLUTION TO THE CRYSTAL TILT

The original concept of the cubic crystal deflector sought to so position the crystal by tilting it relative to the cubic structure of the crystal that atoms of the crystal are forced to effectively occur at successive locations equivalent to a very close, dense positioning of the atoms as seen from the point of view of the purely vertically upward direction of the rays of the Earth's gravitational field. Such positioning would insure that all of the gravitational field is forced to pass extremely close to an atom somewhere in the crystal and to accordingly be deflected away from its natural vertically upward path.

However, the atoms of the Silicon cubic crystal lattice are not fixed in location relative to each other but, rather, are continuously oscillating or vibrating about their nominal neutral positions.

- The vibrations are of various random amplitudes in a range of amplitudes depending on the temperature-determined energy of the vibrations.
- The vibrations are at various random frequencies again in a range of frequencies depending on the temperature.
- The motion of the atoms in their vibration spans a range of locations encompassing a large number of atomic positions that would have been sought to be achieved in various different layers somewhere in the crystal under the original concept and plan.
- That range of motion of the atoms is a small fraction of the neutral interatomic spacing in the crystal.

The net effect of this behavior of the atoms is that the original concept is unworkable. The natural effects of temperature variation and lattice vibrations are much greater than the precise offset intended of $3 \cdot 10^{-19}$ meter. The effects would overwhelm such a minute setting, which is probably too minute to accurately set in any case.

The alternative is to accept the random vibratory behavior of the atoms and incorporate it into the overall design.

First, the vibrations of each atom are largely independent of the behavior of the other atoms because the amplitude of each atom's vibrations are such a small fraction, 0.0003 , of the interatomic spacing. At any instant of time the totality of the atoms behaving randomly means that, for a sufficient total number of atoms [a sufficiently thick crystal], every sought position of an atom appears somewhere in the crystal. The range of the atom's vibrations can be thought of as a single "super atom" that simultaneously is at all of the $3 \cdot 10^{-19}$ meter intervals in its range.

Second, the issue of the tilt angle and offset that it produces now is that of properly staggering the atomic vibration ranges of the atoms in each layer that same range amount. That is, the tilt objective is now to offset the second layer from the first layer by one atomic vibration range, 0.0003 , of the interatomic spacing, $0.0003 \times 2.7 \cdot 10^{-10} = 8 \cdot 10^{-14}$ meters.

With the "unit" atomic vibration range being $8 \cdot 10^{-14}$ meters then the tangent of the tilt angle to schedule that range at an equal offset, $8 \cdot 10^{-14}$ meters, in each successive adjacent layer is per equation (C-4).

$$\begin{aligned}
 (C-4) \quad \text{Tan(Tilt)} &= \frac{\text{Offset}}{\text{Vertical Layer Thickness}} \\
 &= \frac{8 \cdot 10^{-14}}{5.4 \cdot 10^{-10}} = 0.00015 \\
 \text{Tilt} &= 0.008^\circ
 \end{aligned}$$

Figure C-1, below illustrates the effect of equation (C-4).

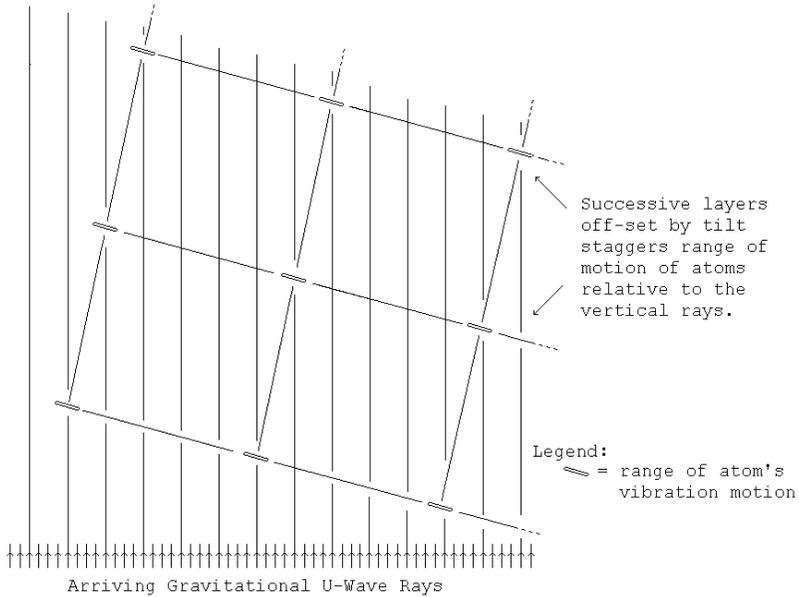


Figure C-1
Cubic Crystal Tilt and Atomic Range of Motion Offset
[Not to scale]

If, instead, the layer to layer offset is set at eleven times the “unit” atomic vibration range of $8 \cdot 10^{-14}$ meters, that is $[11] \times [8 \cdot 10^{-14}]$ meters in each successive adjacent layer the tilt is per equation (C-5).

$$\begin{aligned}
 (C-5) \quad \text{Tan(Tilt)} &= \frac{\text{Offset}}{\text{Vertical Layer Thickness}} \\
 &= \frac{[11] \times [8 \cdot 10^{-14}]}{5.4 \cdot 10^{-10}} = 0.002 \\
 \text{Tilt} &= 0.1^\circ
 \end{aligned}$$

That tilt is a not unreasonable value to implement. With it every eleventh layer picks up the position of the second, then third, etc. layer of the equation (C-4) case, the layer to layer offset being equal to the atomic vibration range.

Using a suitably thick section of a commercially grown Silicon cubic crystal ingot 30 cm in diameter. the equation (C-5) tilt angle tangent of 0.002 would be achieved with a 0.6 mm thick shim at the edge of the crystal.

Going still farther, if, instead, the layer to layer offset is set at one hundred one times the “unit” atomic vibration range of $8 \cdot 10^{-14}$ meters, that is $[101] \times [8 \cdot 10^{-14}]$ meters in each successive adjacent layer the tilt is per equation (C-6).

$$\begin{aligned}
 \text{(C-6)} \quad \text{Tan(Tilt)} &= \frac{\text{Offset}}{\text{Vertical Layer Thickness}} \\
 &= \frac{[101] \times [8 \cdot 10^{-14}]}{5.4 \cdot 10^{-10}} = 0.015 \\
 \text{Tilt} &= 0.86^\circ
 \end{aligned}$$

That almost 1° tilt is a reasonable value to implement. With it every 101st layer picks up the position of the second, then third, etc. layer of the equation (C-4) case, the layer to layer offset there being equal to the atomic vibration range.

Using a suitably thick section of a commercially grown Silicon cubic crystal ingot 30 cm in diameter. the equation (C-6) tilt angle tangent of 0.015 would be achieved with a 4.5 mm thick shim at the edge of the crystal.

PRECISION AND ERRORS

If the intended 4.5 mm thick shim were in error by, for example, about ± 0.5 mm then the actual tilt angle tangent would be about 0.013 to 0.017. That corresponds to the multiple of the “unit” atomic vibration range being about 87.75 to about 114.75.

Either value or any others in that range will eventually produce all of the desired configurations given sufficient layers.

Another precision issue is that of the orientation of the cubic crystal. For the tilt angle to be precise, the bottom of the cubic crystal slab must be exactly one simple layer of the crystal, that is perfectly aligned to the cubic lattice. In addition the surface on which the crystal and shim rest must be perfectly horizontal.

Furthermore, two shims are needed, one for the *x-offset* and one for the *y-offset*. Each must be located at a point on the edge of the crystal corresponding to the midpoint of the interatomic spacing central to the greatest parallel diameter. They must be located at 90° relative to each other, corresponding to two adjacent horizontal sides of the cubic structure.

ANALYSIS OF VARIABLES

There are several quantities or factors bearing on the amount of gravitational deflection produced by a Silicon cubic crystal deflector as here contemplated.

First is the ratio of the U-wave concentration of Earth's natural gravitation as compared to the U-wave concentration in the light diffracted at a slit, calculated at 10^{15} in Appendix B. This ratio determines the closeness required of the passage of gravitational U-waves to atoms of the crystal as calculated in Section 4. This quantity is not variable, but, in spite of Appendix B its value is to some extent an estimate rather than a hard fact. The effect of variation in its value is to correspondingly vary the gravitational U-wave passage atomic closeness needed, which in the strict "fundamental case" varies the precise tilt angle called for. Practically, that is of no significance in view of the above "The Random Distribution Solution to the Crystal Tilt".

However variation in the gravitational U-wave passage atomic closeness needed produces variation in the number of Silicon cubic crystal layers required which translates into variation in the required thickness of the Silicon cubic crystal slab.

Next is the issue of the vibration range of the crystal's atoms. The range of each of the crystal's atom's vibration varies from that of every other atom because the heat energy so stored varies and continuously changes through exchanges. The atoms' average or typical vibration range is taken above to be about $8 \cdot 10^{-14}$ meters. Those ranges and the uniformity over each range of the random distribution of each individual atom's momentary position in the range are approximate and variable.

The extent to which a particular angle of tilt produces comprehensive coverage of the entire crystal by placing the ranges in successive crystal layers exactly adjacent to each other [as viewed by the vertical flowing gravitational U-waves] or, better, sufficiently overlapping, is a variable because the ranges are a variable. The effect of the degree to which that is optimum or not affects the percentage of the total gravitational U-wave flux that is deflected.

In addition the atomic vibrations are three-dimensional although the analysis has treated only one-dimensional vibrations as in Figure C-1.

Finally, the calculated required thickness of the Silicon cubic crystal slab or ingot, 49 cm varies due to all of the above variations. The effect of this is to affect the percentage of the total gravitational U-wave flux that is deflected, also. In general, the thicker the slab the more deflection likely to be achieved.

PRELIMINARY DESIGN SUMMARY

Pending the results of further research and development experiments the principle design parameters for the initial cubic crystal gravitic deflector are as summarized below.

Per the calculations of Section 4, a silicon monolithic cubic crystal slab 50 cm thick or more should result in 100% deflection.

Common commercially produced silicon cubic crystal wafers are on the order of 600 micro-meters [0.6 mm] thick and up to

30 cm in diameter. Using commercial wafers of that type with their very small thickness would be impractical.

Therefore a single thick slab is needed such as is commercially produced to form the ingot from which the commercial wafers are sliced.

With regard to the distance from the top of the cubic crystal deflector to the bottom of the object above it, the greater that distance is the more effectively reduced is the gravitational U-wave flux acting on the object because the scattered rays of gravitational U-wave can more effectively disperse as they have more distance to travel to the vicinity of the object.

The deflector consists of:

- A support having a verified horizontal upper surface for the cubic crystal deflector to rest upon;
- A Silicon cubic crystal slab:
 - 30 cm in diameter,
 - 50 cm or more thick, and
 - with the orientation of the cubic structure determined and noted so that the tilt-producing shims can be properly located at the mid-point of two adjacent sides of the horizontal plane of the cubic structure;
- Precision shims 4.5 mm thick for producing the tilt of the cubic crystal slab: a tilt angle tangent of 0.015 producing a tilt angle of 0.86°. on the 30 cm diameter Silicon cubic crystal slab.