The mechanism of nuclear spontaneous time reversal symmetry breaking transferred to digital logic system

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Abstract. Spontaneous time-reversal symmetry breaking in the system of an atomic nucleus is discussed on the basis of nuclear chirality phenomenon. The mechanism of nuclear chirality i.e. existence of three aplanar angular momenta vectors seems to be applicable in other fields of physics, for example in classical physics as coupling of three gyroscopes. Here, possible application of spontaneous time-reversal symmetry breaking in the design of a digital logic is discussed as an interesting curiosity.

1. Introduction
Possibility of time-reversal symmetry breaking is a fundamental question since the beginning of the quantum mechanics. Mechanisms of T-violation are not fully understood until today. There is room for T-violation in the field of high-energy physics since some elements of the KCM matrix may be complex values [1]. This however relates to heavy quark sector and no T-violation is expected to occur in low energy atomic physics. Search for time-reversal symmetry breaking in low energy collective modes of an atomic nucleus is a subject of extensive studies from theoretical as well as experimental standpoint since years. Variety of techniques, like gamma-gamma correlations [2, 3], Electric Dipole Moment measurement [4] or even mixing of chirality doublets [5, 6] were proposed in order to find T-violation in low energy nuclear physics. Finally, the possibility of time-reversal symmetry breaking in atomic and molecular physics could have large impact on industry due to its possible technical applications, for instance, an increase of security of digital network technologies. In contrast to fundamental T-violation it is relatively easy to find occurrence of spontaneous time reversal symmetry breaking. In the field of nuclear spectroscopy this phenomenon is known as nuclear chirality. Thus a question of a digital logic based on spontaneous T-symmetry breaking becomes an interesting subject that is briefly discussed here.

2. Nuclear chirality
In the most simple case, the phenomenon of nuclear chirality appears in odd-odd nuclei that are triaxially deformed. Such nuclei may be described as coupling of three elements: odd proton, odd neutron and an even-even triaxial core. The angular momentum vectors of the core, of the odd proton and of the odd neutron may be perpendicular to each other forming a system with specified handedness. The sign of the handedness is chosen spontaneously by the system and may be reversed by action of time-reversal operator, thus we deal with spontaneous time reversal
symmetry breaking. The picture of nuclear chirality is based on coupling of three gyroscopes and seems to be applicable in other fields of physics. In ref.[7] it has been shown that such a coupling has similar behavior in nuclear as well as in classical physics. Treating the sign of the handedness as a bit of information one can obtain a logic that changes the bit values with the time-reversal. Such digital logic could be useful to prevent reverse computing or make isomorphic transformations being irreversible due to spontaneous T-violation.

3. Spontaneous time reversal symmetry breaking in the unit of information - rotating bit

The coupling of three gyroscopes in case of nuclear chirality ensures that the system is rotationally invariant. Therefore the sign of the handedness does not change with rotation of the system. Rotational invariance in the case of digital logic means that the behavior of the unit would be invariant with the change of its connectors. Modification of connections of the memory unit that is etched in a memory chip goes beyond the scope of this report as well as beyond the capabilities of a regular pc users. Therefore, the rotational invariance is not vital for spontaneous T-violation in the digital logic what reduces the problem of three to the problem of only one gyroscope. The rotation direction of a gyroscope changes to opposite with time-reversal. One gyroscope can easily be modeled by the logic of 2 bit counter that for instance changes its state on the down-slope of the clock signal - see fig. 1. Such a counter consists of two T-flip-flop units triggered by the down-slope of the clock signal. Going backward with time one can see reversed behavior of the flip-flops i.e. they change their states on the rising-slope of the clock signal - see fig.2. This modifies the behavior of the counter - after time-reversion it counts in opposite direction. Therefore, the counter is a good model of a physical gyroscope. The last thing that remains is to engineer an equivalent to the sign of the handedness of the chiral nucleus. The analog in the case of one gyroscope is the sign of rotation: +1 value for clockwise, -1 value for anticlockwise rotation. In the case of digital counter the analogy is the following: bit value 1 for counting up, 0 for counting down. Example of a logic that measures direction of counting consists of two D flip-flops, two EX-NOR gates and one triple triple AND gate connected to the same clock signal - see fig.3.

To check the direction of counting one has to compare the current with the previous state of the counter. Therefore the signals from counter are branched in two parts. First part is unchanged and keeps the present state of counter and the second part goes into the D flip-flops (triggered by the rising slope of the clock signal) that act as a delay. Signals leaving the D flip-flops in the second branch represent the previous state of the counter with respect to the signals in the first branch. The role of the EX-NOR and the triple AND gates is to compare the current and the previous state of the counter. The gates give clock signal in case of counting up and zero in case of counting down as an output signal. Using the analogy with the physical
Figure 2. State change of the flip-flop unit with respect to clock signal. Left: flip-flop unit that changes state on the down-slope of the clock signal. Clock signal is plotted with thick solid line on top of the picture. Large arrow at the bottom shows the direction of time-flow. In between the change of the flip-flop state (from previous to the current state) is symbolically plotted with small arrow and dashed vertical line. Right: working of the flip-flop unit with reversed time. One can see that the triggering changes from the down-slope (left part) to the rising-slope (right part).

Figure 3. Rotating bit logic – a digital logic consisting of the two-bit counter and a part designed to check the direction of counting. The two bit counter (SN7493) is placed on the left. The output signals from the counter are branched in two parts. The first part remains unchanged (gray color) while the second part goes into the SN7474 unit consisting of two flip-flops triggered by the rising-slope clock signal. The SN7474 unit works as a delay with respect to clock signal giving the previous counter state as an output. Two EX-NOR and the TRIPLE-AND gates compares the previous state of the counter with its current state determining the counting direction. It gives clock signal in case of counting up and zero in case of counting down as an output. See text for more details.

gyroscope, the described logic represents a ‘rotating bit’ that gives the clock signal (1 value) for clockwise rotation and zero (0 value) for anticlockwise rotation.

In order to see the analogy of the ‘rotating bit’ and the physical systems one needs to verify the response of the digital logic to action of time reversal symmetry. In the chiral nucleus, time-reversal changes the sign of the handedness. To have a rotating bit that breaks spontaneously the time reversal symmetry we expect similar behavior: time reversal changes the logic output form +1 value (clock signal) to 0 value and vice-versa. The only thing the time-reversal changes in the presented logic is the behavior of the flip-flops used. As discussed above the flip-flops in the counter unit change their triggering form downslope to rising-slope of the clock signal.
Similarly the D flip-flops, used to compare the current and the previous state of the counter, change their triggering form rising-slope to down-slope of the clock signal. The remaining logic (including clock) is T-symmetric. The response of the logic output on time reversal is shown in fig.4 and in fact it corresponds to physical systems with spontaneously broken symmetry.

![Figure 4. The signals in the rotating bit logic as a function of time. Left: the signals plotted for the counter set to counting up. The counter (SN7493) is triggered on the down-slope of the clock signal giving QB, and QC signals as an output. The SN7474 unit is triggered on the rising-slope of the signal giving 1Q and 2Q outputs. The output signal repeats the clock signal in that case. Right: The same logic in the time-reversed frame. Now the SN7493 is triggered on the rising-slope of the clock signal while the SN7474 on the down-slope giving zero as an output signal. This presents possible spontaneous time-reversal symmetry breaking of the logic.]

4. Summary

Quest for time reversal symmetry breaking continues to be a subject of intensive study in various filed of the physics science. In the context of high energy physics the T-violation is a fundamental problem connected to the structure of the matter while in the low energy region the phenomenon relates to substantial possibilities of technical applications. Here the occurrence of spontaneous time reversal symmetry breaking was discussed, which is known since years in nuclear spectroscopy science. A transfer of this phenomenon to a model of the digital logic was shown as an interesting curiosity.

References

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