Nanoring as logic gate and memory mass device

Dario Cricchio and Emilio Fiordilino

Dipartimento di Fisica e Chimica, Universit`a di Palermo, Via Archirafi 36, 90123 Palermo (Italy)
dario.cricchio@unipa.it

Abstract

We study the application of one nanoring driven by a laser field in different states of polarization in logic circuits. In particular we show that assigning boolean values to different state of the incident laser field and to the emitted signals, we can create logic gates such as OR, XOR and AND. We also show the possibility to make logic circuits such as half-adder and full-adder using one and two nanoring respectively. Using two nanorings we made the Toffoli gate. Finally we use the final angular momentum acquired by the electron to store information and hence show the possibility to use an array of nanorings as a mass memory device.

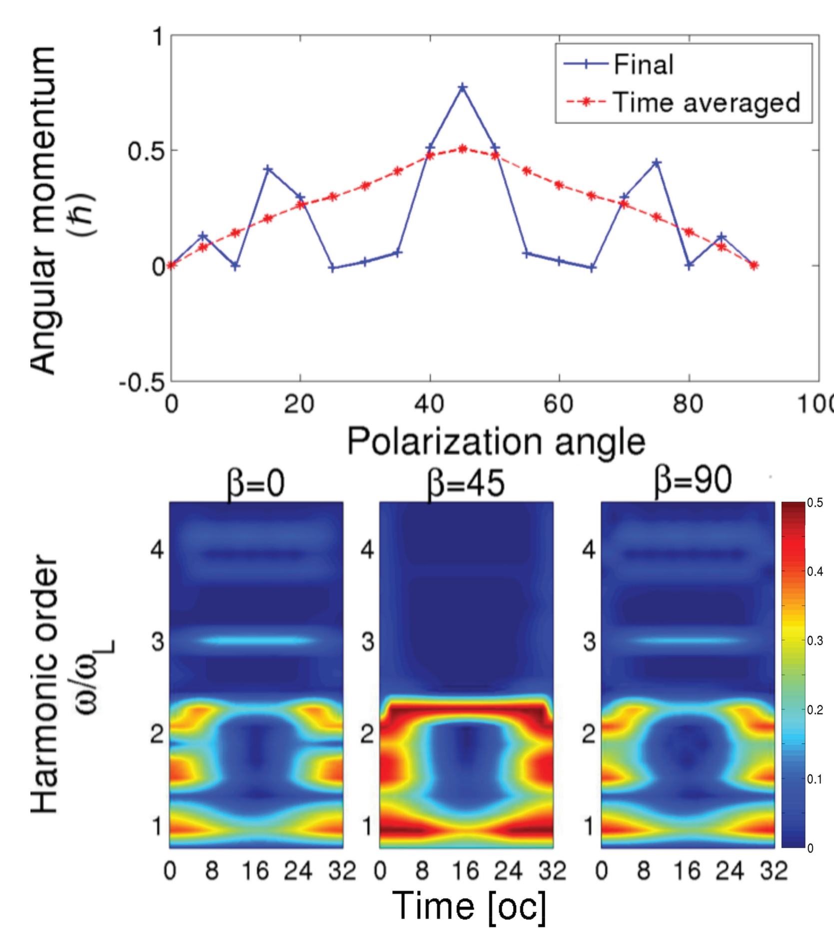
Introduction

This work deals with the possibility to use nanorings, driven by a laser field, as logical gates.
Our system is composed by one nanoring, with only one active electron, driven by an elliptically polarized laser field. We calculate the harmonics and the Raman lines emitted and the angular momentum acquired by the electron in different states of polarization of the incident laser field. The process that we use in this work is the high harmonic generation (**HHG**).

Then we calculate the HHG spectra and, from the use of the wavelet transform, we recognize the presence of a signal composed by the first two harmonics and the Raman lines. We made these calculations varying the states of polarization of the incident laser field. We also calculate the angular momentum acquired by the electron and with all these information obtained, we create a truth table of logical operations to use the nanoring as a logic gate. We also make some example of implementation of nanoring to construct a basic logic circuit such as the half and the full-adder. We can also construct a reversible logic gate: Toffoli gate, using two nanorings. Finally we discuss the possibility of constructing a memory mass device using an array of nanorings.

Methods

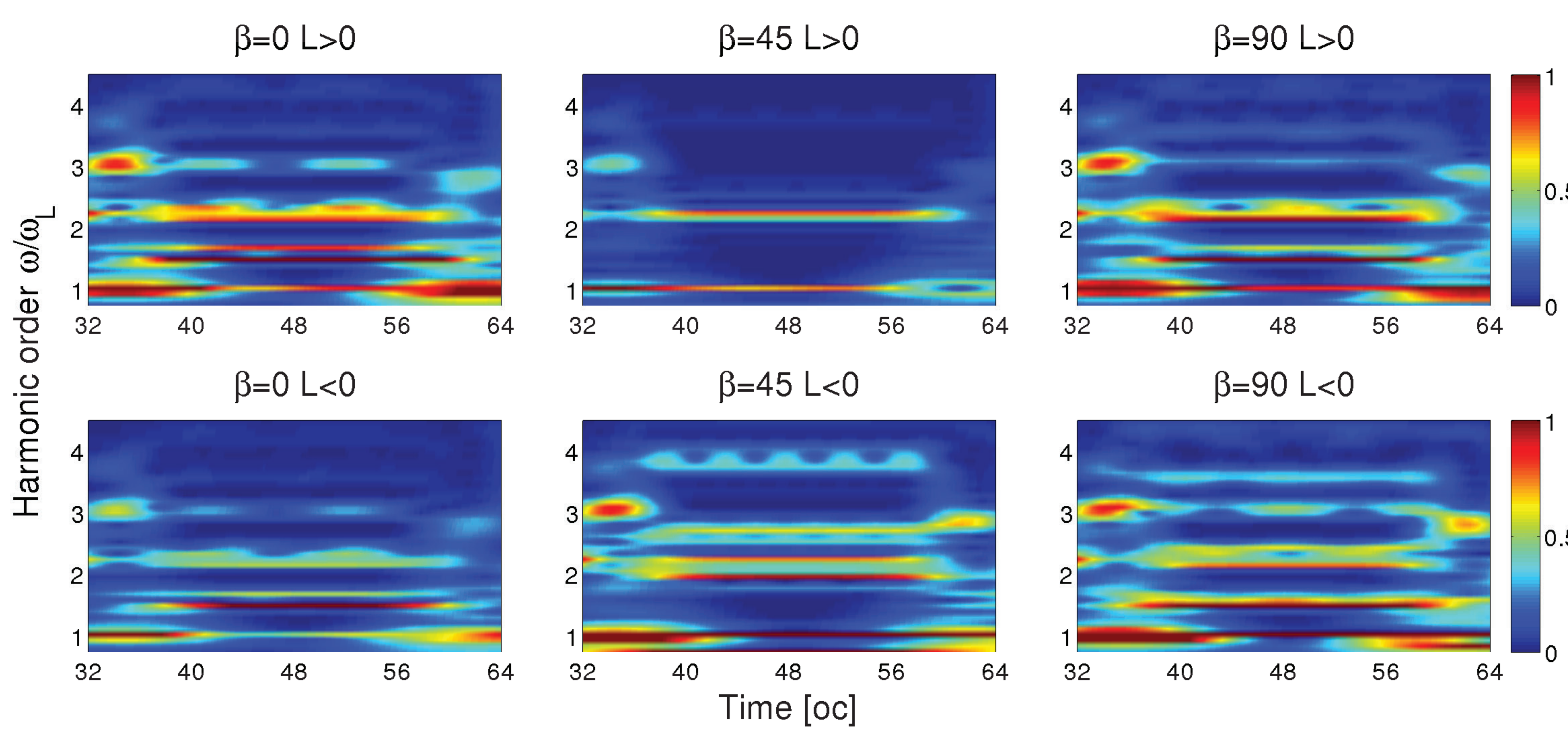
In our calculations we use a laser intensity of **I=10^{14} W/cm^2** and a radius of **R=2.7 au**.
To understand when a signal is present, we performed a Morlet wavelet analysis of our data. Contrary to the time Fourier transform, wavelets have a variable resolution in time and frequency. This process permit us to study the time evolution of the spectra and hence to understand when a signal is present.
We indicate with **I** and **II**, the first two odd harmonics of the spectrum, with $\mathbf{R}_1$ and $\mathbf{R}_2$ the signals corresponding to the Raman transitions and with $\mathbf{L}_z$ the presence of a final angular momentum.
We also can use the angular momentum acquired by the electron in the nanoring to store information. In fact we can consider the final angular momentum like a pseudo-spin that can be reversed by changing the direction of circular polarization of the incident laser field.



$\mathcal{E}_{x,y}$	I	II	R_1	R_2	L_z
0 0	0	0	0	0	0
1 0	1	1	1	1	0
0 1	1	1	1	1	0
1 1	1	0	1	0	1
$L=0$	OR	XOR	OR	XOR	AND

Table 1: Truth table: in input we have the laser states $\mathcal{E}_{x,y}$ and in output we have the first two odd harmonics, the Raman transitions and the final angular momentum.

Figure 1: Top: Final (solid line) and time averaged (dashed line) angular momentum obtained using a laser photon of **2 eV** with an intensity of**10^{14} W/cm^2**.
Bottom: Morlet wavelet analysis of the dipole moment for **β=0°, 45°, 90°**.



$\mathcal{E}_{x,y}$	H_1	H_{II}	H_{R1}	H_{R2}	L_z
0 0	1	0	1	0	1
1 0	1	1	1	0	1
0 1	1	1	1	0	1
1 1	1	0	1	0	1
L>0	BUFFER	XOR	BUFFER	RESET	BUFFER

$\mathcal{E}_{x,y}$	H_1	H_{II}	H_{R1}	H_{R2}	L_z
0 0	1	0	1	0	1
1 0	1	1	1	0	1
0 1	1	1	1	0	0
1 1	1	1	1	1	0
L<0	BUFFER	OR	BUFFER	AND	//

Table 2: Truth table: in input we have the laser states $\mathcal{E}_{x,y}$ with a initial positive angular momentum (top) and with a negative initial angular momentum (bottom). In output we have the first two odd harmonics, the Raman transitions and the final angular momentum.

Figure 2: Morlet wavelet analysis of the dipole moment with **ħω$_L$=2 eV** and **I$_L$=10^{14} W/cm^2** and **R=2.7 a$_0$** for **β=0°, 45°, 90°** and an initial angular momentum **L > 0** (top line) and **L < 0** (bottom line).

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