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Internship report

Simulation of the Smith-Purcell radiation and designing stepper motor control system

Part II

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Smith-Purcell Radiation

Smith-Purcell Radiation (SPR) is radiation that is caused by a charged particle passing near a periodical conductive grating. It can be used as the source of the radiation in milimeter range or as a bunch profile measurement method.

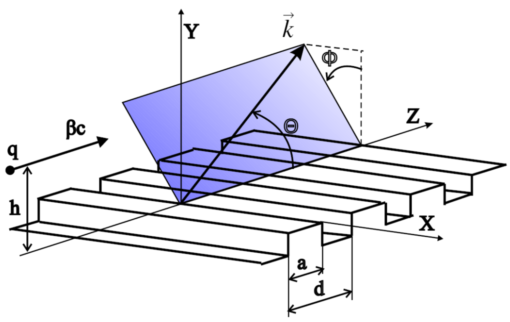

Figure 1: Volume grating [3]

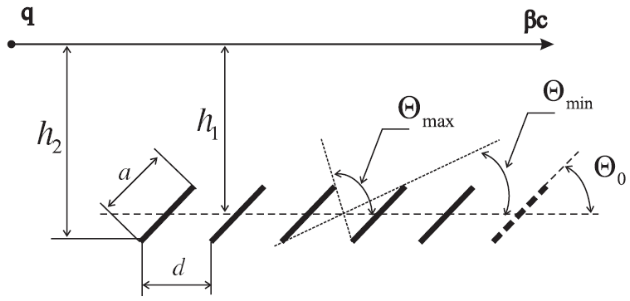

Figure 2: Thin strip grating [3]

Far and pre-wave zone

In [2] authors explained that intensity of radiation per solid angle at relatively big distances (far zone) are different from ones at close distances (pre wave zone), it is also referred as "Pre-Wave" effect. After simple geometrical relations they received so called far zone criterion, which shows us whether we are in the far zone:

$$R_{far} \gg N^2 d(1 + \cos\theta)n \tag{1}$$

where R_{far} our criterion, d- period(pitch) of the grating, N- number of periods along the beam direction n - order of radiation.

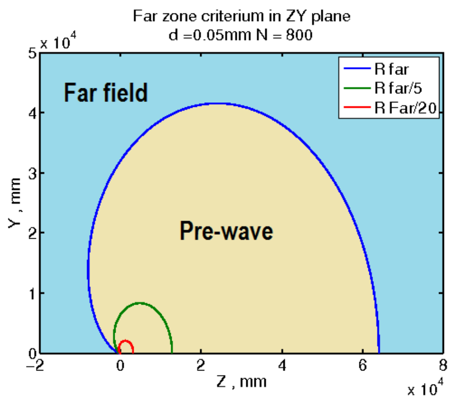

Figure 3: Far zone criterion in the YZ plane of Fig.1

Simulation of SPR

One could use SPR as instrument for measuring bunch profile. There are several models to describe SPR and thus measure bunch profile with the help of it, but some of them are so-called "far" models, in which radiation is in far zone regardless of the distance between grating and detector. But in reality, there are "Pre-Wave" effect, so real signal is different from what far models predict. So it is important to know ratio between far zone intensity and pre-wave zone intensity referred to as correction factor.

My task was to study model proposed by Potylitsyn and Karlovets in [2] simulate it and calculate correction factors for given parameters.

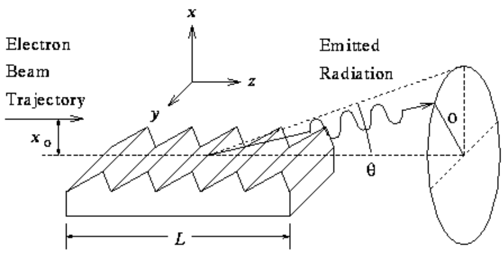

Figure 4: Grating in the shape of teeth

The idea of Potylitsyn and Karlovets is to use relation of already known effect - backward diffraction radiation(BDR). Which says that when charge passing nearby conducting surface each point of this surface is source of radiation with phase difference from distances to each source and from time difference of charge passing points of this surface at finite speed. In [2] authors applied BDR model to the shape of periodical flat conducting strips. But my task was to simulate this model for 3 dimensional teeth Fig. 4, so I modified this model, as it has very basic principles.

But at the same time it takes a lot of time to simulate radiation intensity using model proposed by Potylitsyn and Karlovets, as it contains double integral from Bessel function, so it requires simplification.

One simplification is to measure far zone intensity for this model, it could be easily done if one assume that distance between source of radiation and detector is infinitely large relative to the size of the grating, and it greatly decreases calculation time. This simplification is further referred to as far model.

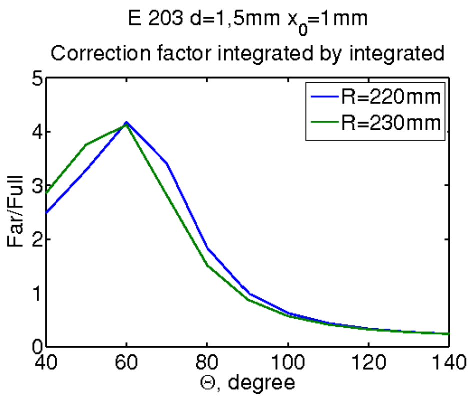

Figure 5: Correction factor normalized by value at $\theta = 90°$. d=1.5mm

Second simplification uses fact that, even if grating is not small relative to the grating-detector distance, period of the grating is much smaller than this distance, like this we are in the pre-wave zone, but formula for the intensity is more simple than the original one. Also, as calculations were taking long because of large number of points, it was also possible to use parallel computation built-in the MATLAB. This one referred to as short(full model).

The simulation were done and on the Fig.5 it is clearly visible that this correction factor makes considerable contribution into if one want to compare experimental results with far zone model. If these correction factors are applied it would change the shape of the measured profile.

Step motor control system

In [1] I described system to control stepper models. It could be easily expanded to be able to control multiple motors. The program to communicate with this controller was made by me and tested to be able to send and receive commands properly, to be easy and convenient to create complex sequences of commands.

During this internship, thanks to the Nicolas Delerue, I was able to use this system in real environment. It was used at PHIL(LAL) and SPARC(Frascati), with different kind of set-up. After some configuration and recalibration of positioning it become possible to operate motors remotely, which enables to change parameters of the experiment without being in the accelerators rooms.

At the end of working with motors I learned how to add modules to WAGO controller different from stepper controllers, and added ADC and made commands to get its values. As result I received programm for WAGO controllers that could be used with multiple number of motor and else different devices such as ADC.

Future plans

I am planning to understand more deeply results of my SPR simulation, compare new results with already existing far models and understand differences between them.

Also it would be good to structurize simulation code so it would become more compact and easier to understand.

Thanks

Thanks to my supervisor Nicolas Delerue, LAL, V. N. Karazin Kharkiv National University, all my family and friends, for giving me support and possibility to go on this Internship, I liked it very much!

References

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