საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 8, №3, 2014
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 8, no. 3, 2014

Physics

Ferromagnetic Spiral in Permanent Magnetic Field and its Application

Vladimer Kortkhonjia

E. Andronikashvili Institute of Physics, Tbilisi

(Presented by Academy Member Nodar Tsintsadze)

ABSTRACT. The creation of pulse transformer at high voltages is an important technical problem. In the paper it is shown that using a spiral made of ferromagnetic material, e.g electric steel "Armco", in the longitudinal magnetic field, the pulse voltage can be multiplied. This multiplication is described well by the empirical expression $V = V_0\ e^{\mu \cdot n}$, where V is the multiplication of pulse voltage on the spiral turn, V_0 is the pulse voltage applied from the capacitor battery. From the side of the grounded part of spiral the "white" radiation is emitted being connected with plasma glow. Plasma is created by an intensive electron flux. The electrons are generated as a result of a cold explosive emission in the spiral turn. Their current is of the order of 30 kA. The spiral emits the high-frequency radiation at the distance of 30 cm from the spiral and is of the order of 20.5 kV. A source of pulse X-ray radiation, X-ray laser, as well as tiny electron accelerator, can be created. *© 2014 Bull. Georg. Natl. Acad. Sci.*

Key words: *multiplication of high-voltage pulse, ferromagnetic spiral in permanent magnetic field, optical radiation.*

The creation of pulse transformer at high voltages is an important technical problem.For this purpose the properties of ferromagnetic spiral in permanent longitudinal to spiral axis magnetic field were studied. Any ferromagnetic material can be used for spiral. The electric steel "Armco" is preferable. The spiral was placed in longitudinal to spiral axis magnetic field with the strength of several hundreds of Oe. The pulse voltage from capacitor battery was applied to one end of the spiral and the second end was grounded [1, 2]. The multiplied pulse voltage was measured on spiral turns. It was shown that in the spiral (Fig. 1) made of ferromagnetic material, e.g. electric steel "Armco" placed in longitudinal magnetic field with the strength of 0.045 T (Fig.1), the multiplication of pulse voltage from capacitor battery applied to the spiral takes place. On the forth turn of the spiral the voltage after multiplication reached 73.3 kV, when the pulse voltage of 5.0 kV amplitude from the capacitor battery was applied to the spiral. This multiplication is described well by the empirical expression $V = V_0\ e^{\mu \cdot n}$, where V is the multiplication of pulse voltage on the spiral turn, V_0 is the pulse voltage applied from the capacitor battery, μ is the con-

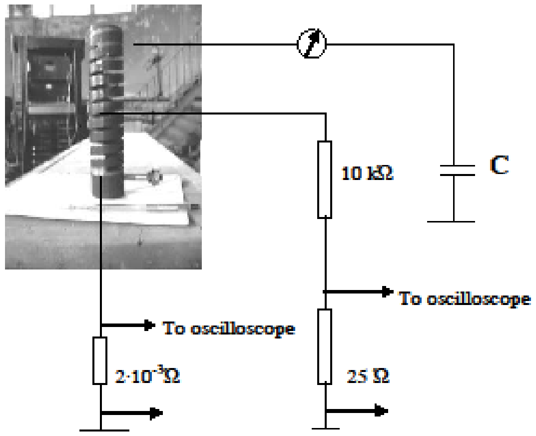

Fig. 1. Schematic diagram of the experiment.

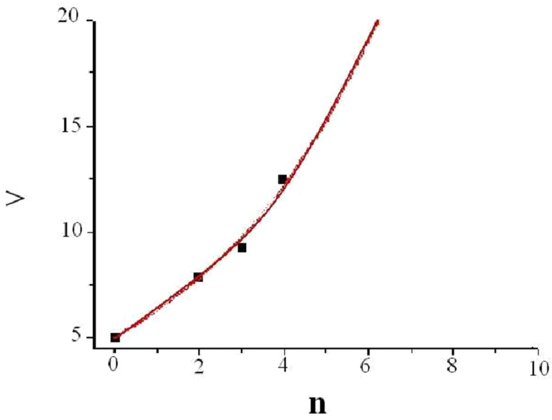

Fig. 2. Dependence of the multiplied pulse voltage V in kV on the number of spiral turns n.

stant characterizing the magnetic properties of spiral, and n is the number of spiral turns.

Fig. 2 shows the plot of this expression with the experimental results. Constant μ for iron is 0.233 and for "Armco" - 0.607.

One peculiarity of ferromagnetic spiral in longitudinal magnetic field should be noted. The position of magnetic field pole relative to the place of application of pulse voltage from the capacitor battery plays an important role. When the north pole was on the side of application of pulse voltage from the capacitor battery, and the south pole on the side of spiral grounding, the multiplication of pulse voltage applied from the capacitor battery goes from the south pole to the north one. The spiral turn nearest to the south pole plays the role of the first turn. The amplitude of the multiplied pulse voltage is small on it and it increases by exponential law towards the north pole. On the turn nearest to it the multiplied pulse voltage is the largest for the given spiral. When the south pole of the permanent magnetic field was on the side of application of pulse voltage from the capacitor battery, the role of the first turn was taken by the turn nearest to this pole.

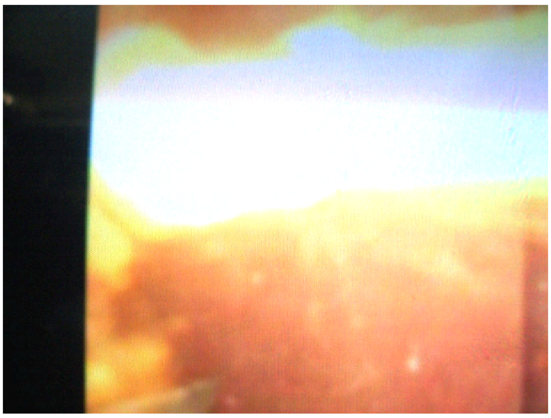

Fig. 3. Photo of plasma glow and electron flux from the spiral.

On the side of grounded part of spiral the "white" radiation is emitted, being connected to plasma glow. Plasma is created by an intensive electron flux. The electrons are generated as a result of cold explosive emission from the spiral turn.Their current is of 30 kA. order.

Fig. 3 shows the photo of electron flux from the spiral, and Fig. 4 presents the oscilloscope traces of electron flux from the spiral.

The ions come from the high-voltage side of the spiral. Their current is of order 12 kA.

The creation of electron flux with such current amplitude is the most important property of ferromagnetic spiral in the permanent longitudinal magnetic field. This fact is very significant from the view point of its application.

In front of the spiral the grounded aluminum foil of 0.5 mm thickness was placed. The electrons burnt through this foil. The diameter of the hole is of the order of inner diameter of the spiral – about 6 mm.

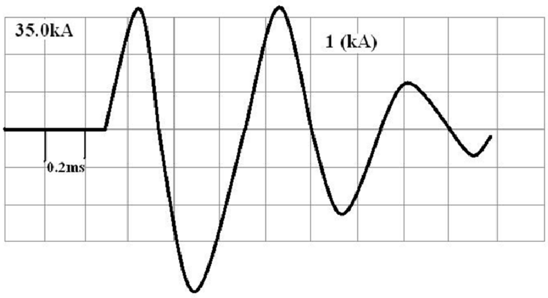

Fig. 4. Oscilloscope traces of electron flux coming from the spiral ("Armco" material)from the grounded side in the permanent longitudinal magnetic field. Pulse voltage applied to the spiral - 4 kV.

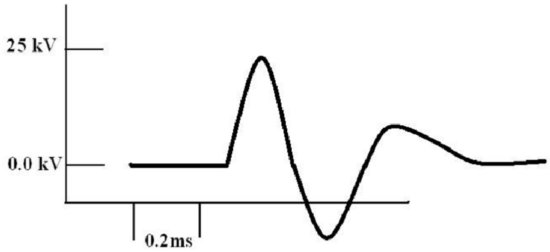

Fig. 5. Oscilloscope traces of the high-frequency pulse. Pulse voltage applied on the spiral – 4 kV.

When the grounded aluminum foil was shifted by 5 cm, the diameter of the hole was decreased and became 2 mm.

The spiral emits high-frequency radiation at the distance of 30 cm from the spiral and is of the order 20.5 kV. The amplitude of this radiation is registered by horn-type antenna designed for 3 cm range.

The electron flux coming from the spiral into the atmosphere is retarded. The role of "anticathode" is played by the grounded end of the spiral. As a result, the pulse X-ray radiation is originated. It is wide. In the given case this device is similar to the usual X-ray tube, differing by the fact that it operates at the atmosphere pressure. For operation of this device there is no need in high-voltage transformer with the voltage of the order of tens of kV, the voltage of 5kV is quite enough. The voltage necessary for X-ray radiation is generated by the spiral itself.

The electron flux from the spiral passes through "wiggler". The X-ray laser is created. This is a free-electron laser. Such lasers already exist but the given one differs in that it operates at the atmosphere pressure owing to a large electron flux from the ferromagnetic spiral. At the distance of 12 m, in foam plastic a trace of soft X-ray radiation was observed. The diameter of the trace is of the order of 1mm. At the larger distance the diameter of the trace practically does not change.

If we place the whole device in vacuum chamber and choose the corresponding pressure, then:

A tiny electron accelerator can be created with a large current. As the calculation shows (see the expression above), the spiral with 20 turns can multiply the voltageapplied from the capacitor battery up to the voltage of the order of 800 kV. The obtained electron flux with the current of the order of 150 kV will have the relativistic velocities.

If we fill the vacuum chamber with any gas, including the noble gases, we can create a) a tunable source of spectral lines, and b) X-ray laser.

In this case, pumping will be made by the usual X-ray radiation generated as a result of retarding the electron flux (see above). This laser will differ from the existing ones by that the source of pumping will be X-ray radiation, while in the existing X-ray lasers the pumping is made by a powerful infrared laser. In case of realization of the proposed laser, it will be simpler and more compact.

Thus, the ferromagnetic spiral in the permanent longitudinal magnetic field being the pulse transformer has a number of promising properties. It allows, in many cases, not to be connected with the vacuum device due to a large electron current formed in the spiral.

1. First of all, this is a usual X-ray device. In the existing devices the vacuum is necessary. It should be noted that there is no need in high-voltage transformer of tens of kV, as the spiral itself produces the high voltage to be necessary.

2. For a free-electron laser vacuum is necessary. The spiral in magnetic field allows to create a free-electron laser in the atmosphere, owing to a large electron current from the spiral.

Table. Dependence of the amplitude of multiplied pulse voltage on the number of spiral turns. The spiral material is steel 40.

Discharge voltage, kV	Numberof spiral turns	Multiplied voltage, kV	Coefficientof multiplication
5.0	0	5.0	1.0
5.0	2	7.8	1.55
5.0	3	9.2	1.84
5.0	4	12.5	2.50
5.0	8	28.0	5.6

3. One can create a gas laser. The pumping in it is made by X-ray radiation generated by a spiral in the permanent longitudinal magnetic field.

4. One more possibility is given by the multiplication of pulse high voltage existing in the spiral in the permanent longitudinal magnetic field. If the number of spiral turns is large enough, one can really create a tiny electron accelerator at the voltage of the order of 800 kV and at the current of the order of 150 kA.

We should note one peculiarity of the given pulse transformer in that there is a possibility to obtain the pulse voltages with necessary amplitude from the different spiral turns at one and the same time. The Table demonstrates this possibility.

ფიზიკა

ფერომაგნიტური სპირალი მაგნიტურ ველში და მისი გამოყენება

ვ. კორთხონჯია

ე. ანდრონიკაშვილის ფიზიკის ინსტიტუტი, თბილისი

(წარმოდგენილია აკადემიკოს ნ. ცინცაძის მიერ)

ნაშრომში ნაჩვენებია, რომ გასწვრივ მაგნიტურ ველში მოთავსებული ფერომაგნიტური სპირალის მეშვეობით შესაძლებელია იმპულსური ძაბვის გამრავლება, იმპულსური რენტგენის გამოსხივების წყაროს, რენტგენის ლაზერის, აგრეთვე მინიატურული ელექტრონების ამაჩქარებლის შექმნა.

REFERENCES

1. *V. Kortkhonjia* (2011) in: Materials of the International Scientific Conference ”Modern Issues of Applied Physics”: 76-80, 30 March, 2011, Tbilisi.
2. *I.K. Kikoin* (1976) Editor, Tablitsy phisicheskih znatchenii. M. (in Russian).

Received October, 2014