October 30, 2009 CBN 09-8

LITHIUM LENS FOR POSITRONS AND ANTIPROTONS IN COMPARISON[1]

A.Mikhailichenko, Cornell University, LEPP, Ithaca, NY 14853

Abstract. In this report we compare parameters for Lithium lens in use for collection of antiprotons and the one suggested for collection of positrons in ILC.

1. OVERVIEW

In our recent publication we described the Lithium lens design suitable for usage in ILC. All engineering parameters are fixed and the lens is ready for detailed modeling of transit-time processes. General output, however, is that the energy deposited by the beam is much smaller, than the one delivered by running current. For example, the temperature rise in hottest spot at the entrance of the front window is around 35^{o}C-50^o (depending on the position of lens behind the target) after a single train passage, while the temperature raised by the current becomes 170^{o}C [1], [2]. This makes detailed modeling less critical, as the lithium lenses for collection of antiprotons is successfully working under such severe conditions.

Although usage of lithium lens for focusing of (anti)protons is more or less known worldwide, usage of Lithium lens for focusing of positrons remains widely unknown; the only operational Lithium lens for this purpose resides in BINP (see references in [2]).

In this contest it is interesting to compare the suggested Lithium lens for ILC and routinely operational lenses for a/protons.

Support for this investigation obtained from ILC GDE Regional Directorship of America.

2. LENS FOR ILC

Lens suggested for ILC is represented inFig.1. Lithium (92% ^{7}Li and 7.5% ^{6}Li) is located inside a thin wall Titanium-alloy tube having a specific resistance much higher than Lithium.

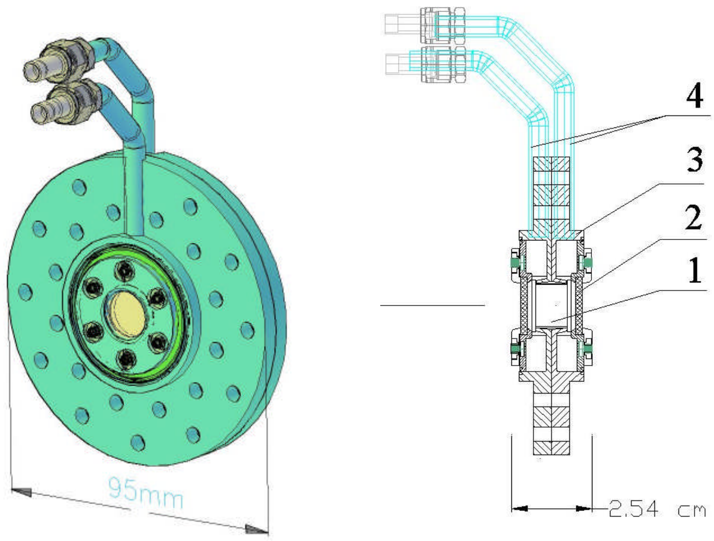

Figure 1: Lens itself is a small insertion at the center; extended flanges serve for electrical contact. 1–volume with Lithium, 2–window (Be/BC/BN), 3–electrical contacts with caverns for Li, 4–tubing for Lithium in/out .

[1] A talk at 6th ILC Positron Source Collaboration Meeting, October 28-30 2009, IPPP, Durham, UK

Specific resistivity of Lithium jumps ~2.68 times at the transition point at ~180^{o}C from 15.44 $\mu\Omega\cdot cm$ to 41.38 $\mu\Omega\cdot cm$, reaching 50.47 $\mu\Omega\cdot cm$ at 300^{o}C, while Titanium alloy has specific resistivity ~180 $\mu\Omega\cdot cm$ at room temperature (Ti-5Al-2.5Sn, low O_2) [3].

In this design we suggested usage of solid contact plates. For this purposes the lens case has extended collars. Saying ahead, the lens for a/protons uses another technique with sphenoid clamps. Lithium lens installed in current duct is shown in Fig.2. All positron source complex is shown in Fig.3.

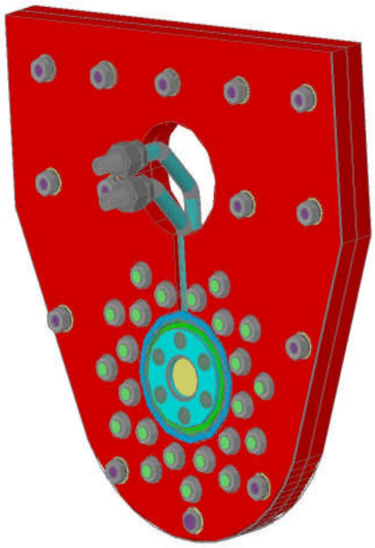

Figure 2: Lens inserted into current duct.

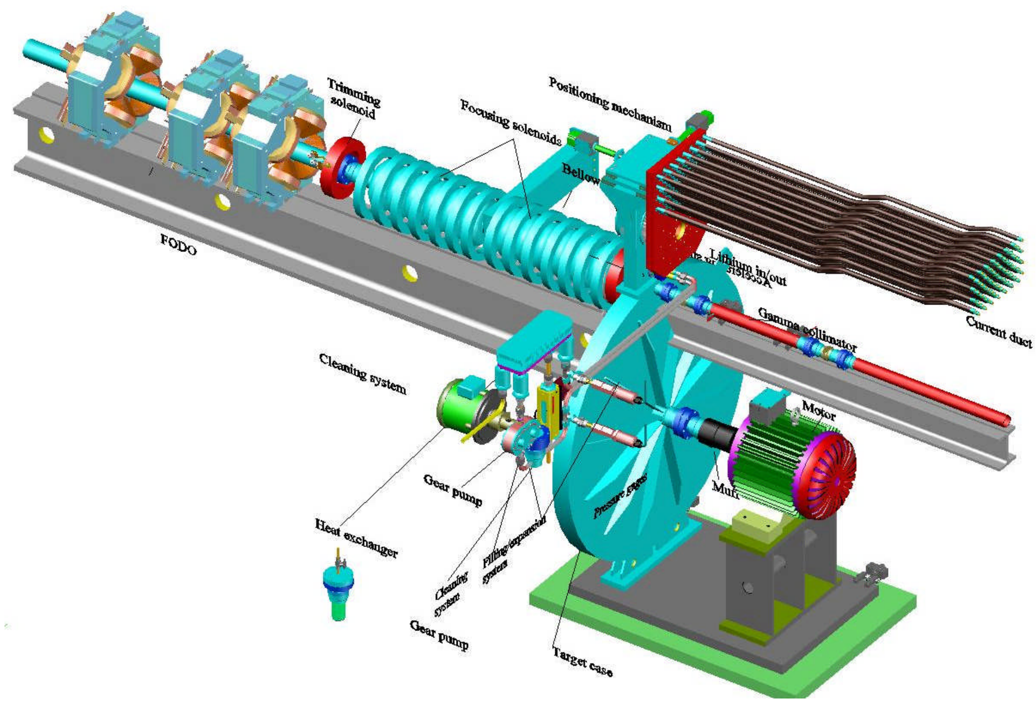

Figure 3: Conversion system assembled with target, gamma-collimator and primary acceleration structure.

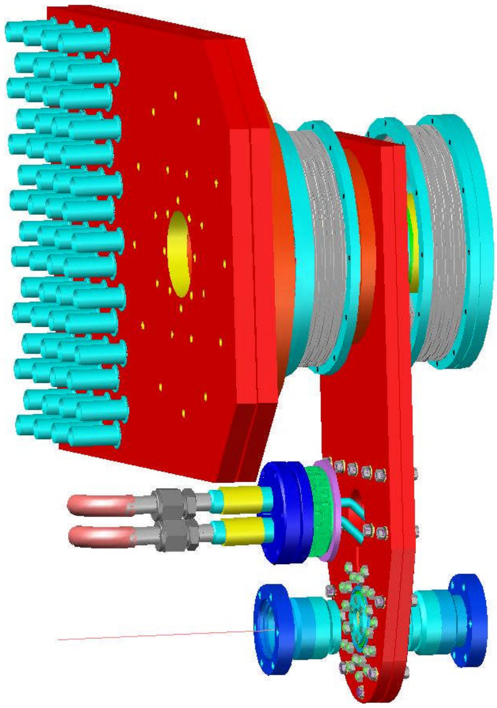

Figure 4: Lens with current duct and vacuum feed-through**.** Vacuumed case not shown.

In Fig.4 the lens is shown installed into current duct, equipped with vacuumed feed through.

3. LENSES FOR ANTIPROTONS

All lenses developed have theirs roots in BINP, Novosibirsk. Such lenses are used at FERMILAB and at CERN. Although it was suggested to use the Lithium lens in antiproton business at both sides of target: for focusing of proton beam to the target and collection of antiprotons from opposite side, the effectiveness of lens for collection of antiprotons was recognized as dominating [4].

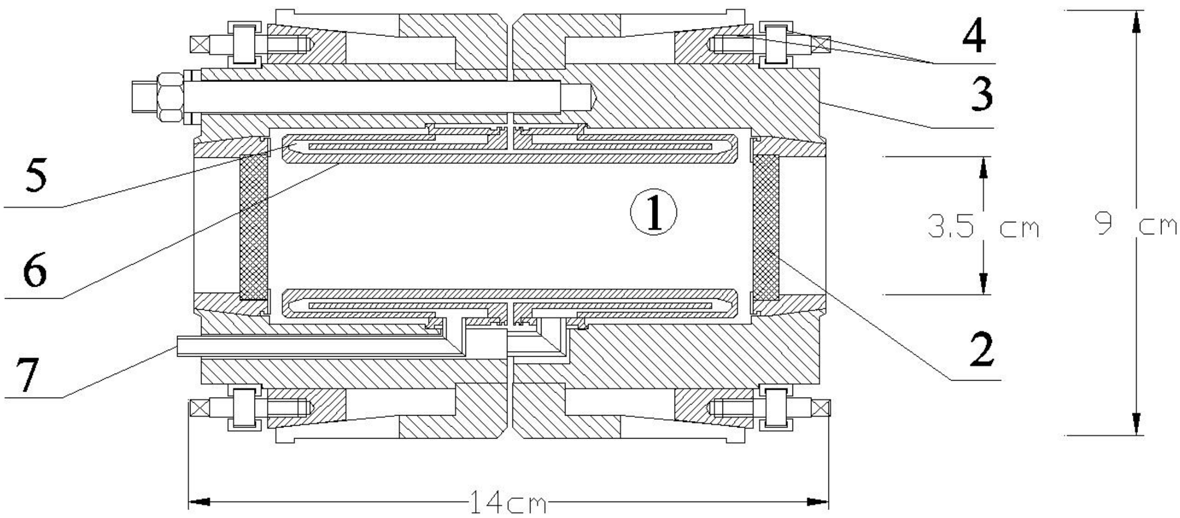

Figure 5: Lithium lens from BINP developed for FNAL. 1–Lithium, 2 –Be window, 3–Case, 4–sphenoid clamps, 5–coolant jacket, 6–Ti cylinder, 7–Coolant in/out.

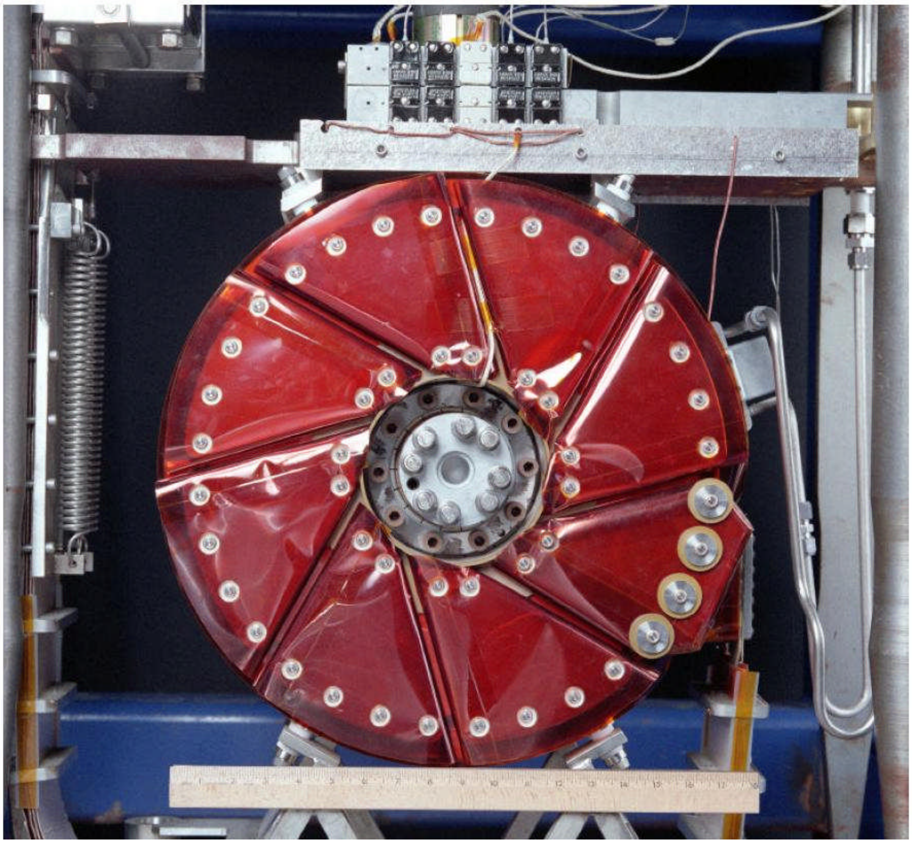

Figure 6: FNAL Lithium lens installed at central part of transformer. Scale is given by the ruler at the bottom of this photo. Photo from [5][2].

Target for antiprotons, typically is made from Nickel of ~7 *cm* long (~half nuclear interaction length) and operates at <1*Hz* repetition rate.

Typical lens lifetime runs from 2 to 8 million pulses averaged over the number of lenses fabricated >22 units. Usually Lithium lens installed at the central part of transformer, so the losses associated with stray fields are minimal here. So the lens and transformer represent an integrated unity. Attachment of lens with sphenoid clamps makes the lenses exchange quick procedure.

For ILC, the transformer is difficult to use (due to longer pulse, awareness of radioactive induction and availability of high current commutators [6]), so we shall use the joints with collars.

.

4. COMPARISON

Lithium lenses drawn with the same scale are shown in Fig.6.

The lens for ILC is rather short, so establishing current flow at the ends of Lithium media may introduce spherical aberrations. However, as the fields remain symmetric these aberrations do not disturb emittance of the collected positrons. (Fringe currents introduce radial field component, which generates azimuthtal velocity). One suggestion on how to compensate these aberrations, represented in [1], is by using windows with a spherical shape. All these aspects will be described in detail in a separate publication.

[2]More pictures of Li lens could be found at:
http://images.google.com/images?client=firefox-a&rls=org.mozilla%3Aen-US%3Aofficial&hl=en&source=hp&q=Lithium+lens&btnG=Search+Images&gbv=2&aq=f&oq=&aqi=

It is clearly seen from Fig 6 from engineering point of view, the lens for positrons is a device with very modest parameters. One can expect that the lifetime will be also much longer. No doubts that this lens could be well operational during few a months period. New materials for windows, such as BN and BC are forced to help in this intention.

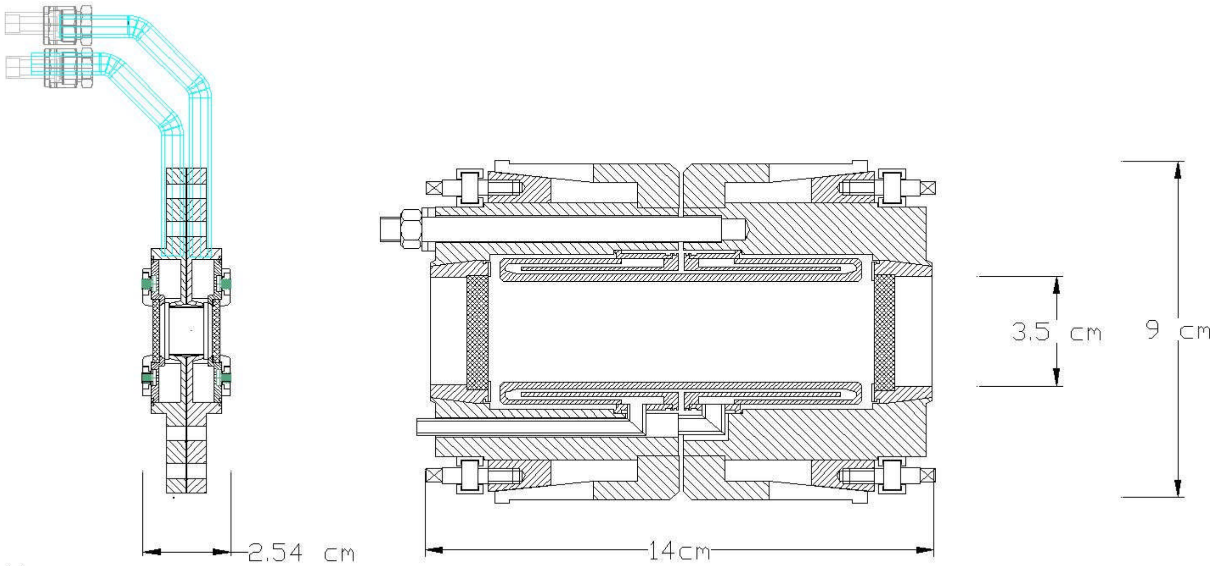

Figure 6: Lithium lenses for positrons and anti-protons represented with the same scale factor.

Parameters of lenses are represented in Table 1. Here the third coulomb is added, however parameters of lithium lens for Neutrino factory are not specified finally.

Table 1. Parameters of lenses for positrons, antiprotons and for neutrino-factory

	Positrons	**Antiprotons**	**Neutrino factory**
Diameter, *cm*	1.4	2-3.6	1.8- 6
Length, *cm*	0.5-1	10	15
Current, *kA*	<150-75	~850	500
Pulse duty, *msec*	~4	0.1	~1
Repetition rate, *Hz*	5	0.7	0.7
Resistance $\mu\Omega$	32	50	27
Gradient, *kG/cm*	<65	55	45
Surface field, *kG*	43	100	80-40
Pulsed Power, *kW*	~720-360	36000	6750
Average Power, *kW*	~15-7.5	3.6	4.7
Temperature gain/pulse, ^{o}K	170-85	80	80
Pressure at axis, *atm*	75-19	400	256-64

One can see that the lens for positrons have highest average power, thanks to repetition rate of 5 Hz. On the other hand it has the lowest axial pressure. Usage of liquid Lithium with external cooling allows drastic reduction of thermal load to the lens body and to the windows.

5. SUMMARY

The lens suggested for ILC positron system is much more compact, than the ones used for collection of antiprotons. All technological challenges could be borrowed from well operated lenses used for collection of antiprotons.

Lens with solid Lithium in operation for about 40 years in BINP gives another example of success of this concept (see references in [2]).

Usage of Lithium lens for positron collection looks guarantied after confirmation made by usage of numerical modeling, that the energy deposition by the beam remains small compared with the direct energy deposition made by the feeding current running through the body of Lithium.

6. REFERENCES

[1] A.Mikhailichenko, "*Lithium Lens* (I)", CBN 09-4, LEPP, Cornell, 2009: http://www.lepp.cornell.edu/public/CBN/2009/CBN09-4/CBN%2009-04.pdf

[2] A.A.Mikhailichenko, "*Lithium lens for ILC positron source*", CBN-08-1, Jan 21, 2008. 21pp., http://www.lepp.cornell.edu/public/CBN/2008/CBN08-1/CBN08-1.pdf

[3] Metals Handbook, Vol 2, 10th edition.

[4] G.I. Silvestrov (Novosibirsk, IYF) ," *Problems Of Intense Secondary Particle Beams Production*", IYF-86-163, Jul 1986. 17pp. Submitted to 13th Int. Conf. on High Energy Accelerators, Novosibirsk, USSR, Aug 7-11, 1986. Published in Novosibirsk Accel.1986 v.2:258 (QCD183:I5:1986); http://ccdb4fs.kek.jp/cgi-bin/img/allpdf?198701402

[5] J.Morgan, "*Lithium Lens Upgrade*", report FNAL, 2002.

[6] S.A. Belyaev, V.G.Bezuglov, V.V.Chibirikin, G.D.CHumakov, I.V.Galakhov, S.G.Garanin, S.V.Grigorovich, M.I.Kinzibaev, A.A.Khapugin, E.A.Kopelovich, F.A.Flar, O.V.Frolov, S.L.Logutenko, V.A.Martynenko, V.M.Murugov, V.A.Osin, I.N.Pegoev, V.I.Zolotovski,"*New Generation of High-Power Semiconductor Closing Switches for Puled Power Applications*", 28 ICPIG, July 15-20, 2007, Prague, Czech Republic, Topic#17, pp.1525-1528.