Planar Chirality

Sergiy L. Prosvirnin

Institute of Radio Astronomy, Kharkiv, UKRAINE

STINT - Kharkiv – December 18, 2017

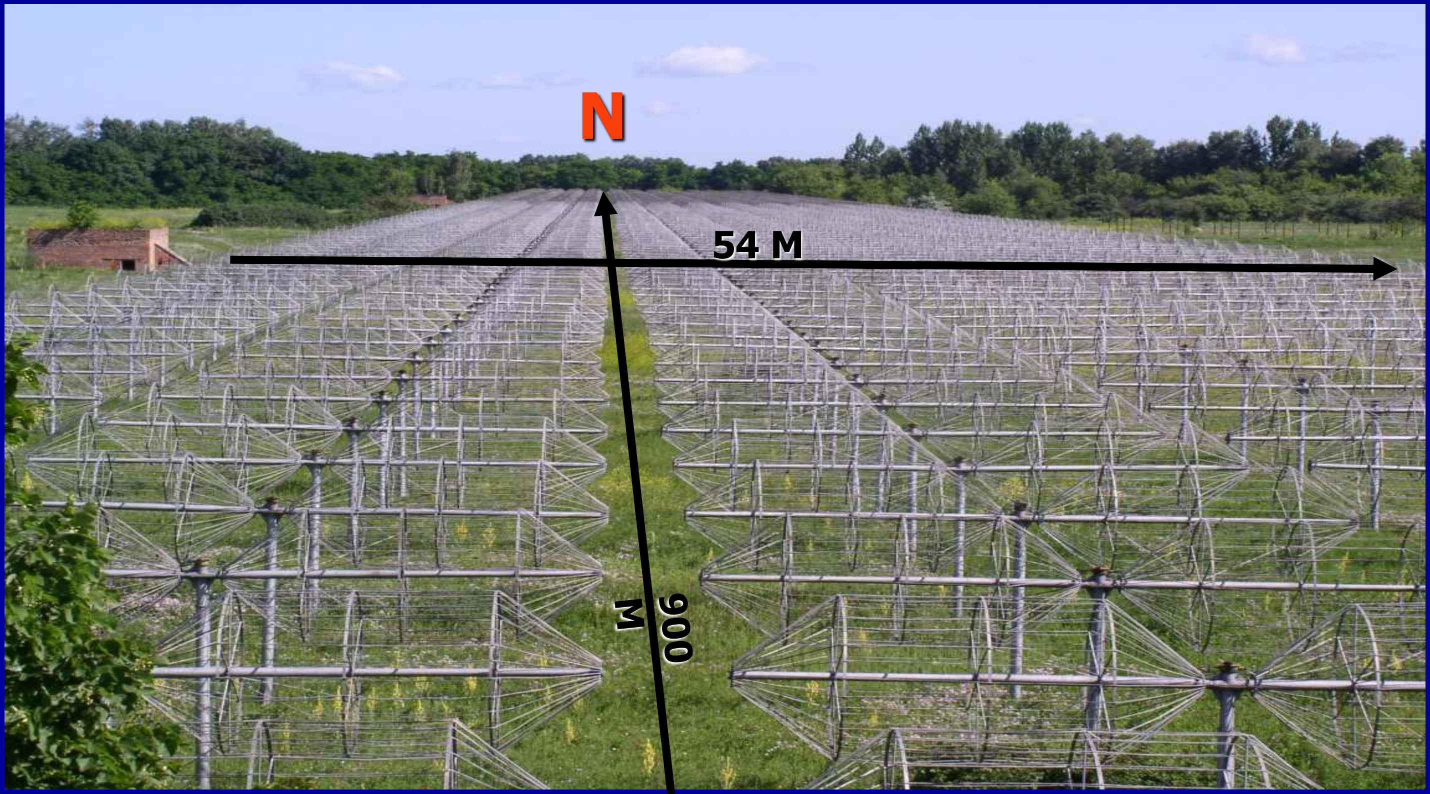
Institute of Radio Astronomy

Research activity tasks:

- investigation of objects in the Universe
- remote sensing of geospace environment and solar system
- physical principles of construction of radio telescopes and radio-engineering systems of remote sensing

http://ri.kharkov.ua/prosvirn/

Ukrainian T-shaped Radio telescope

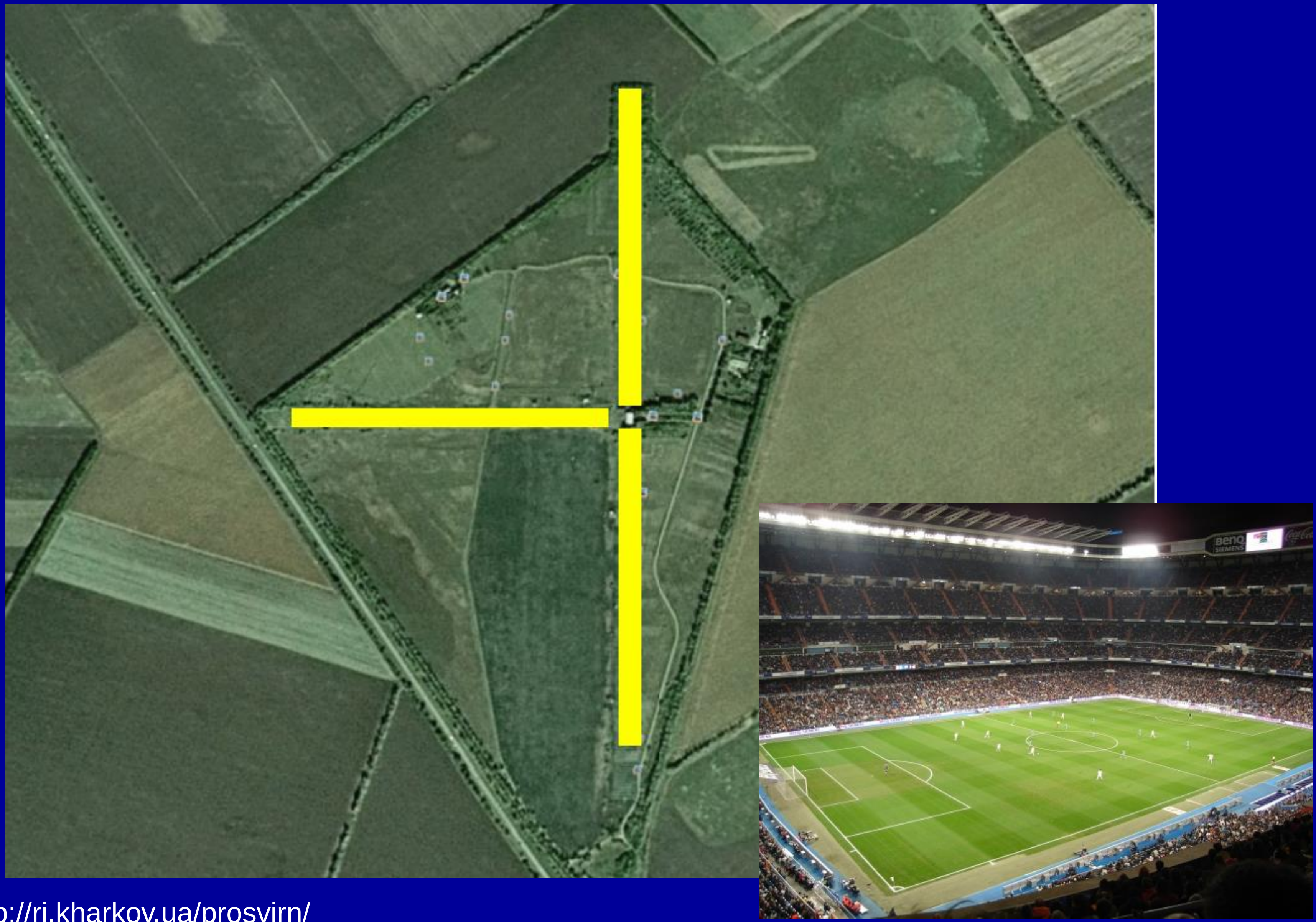


UTR-2: fully steerable & wide band dipoles

A_{eff} = 150 000 m^2

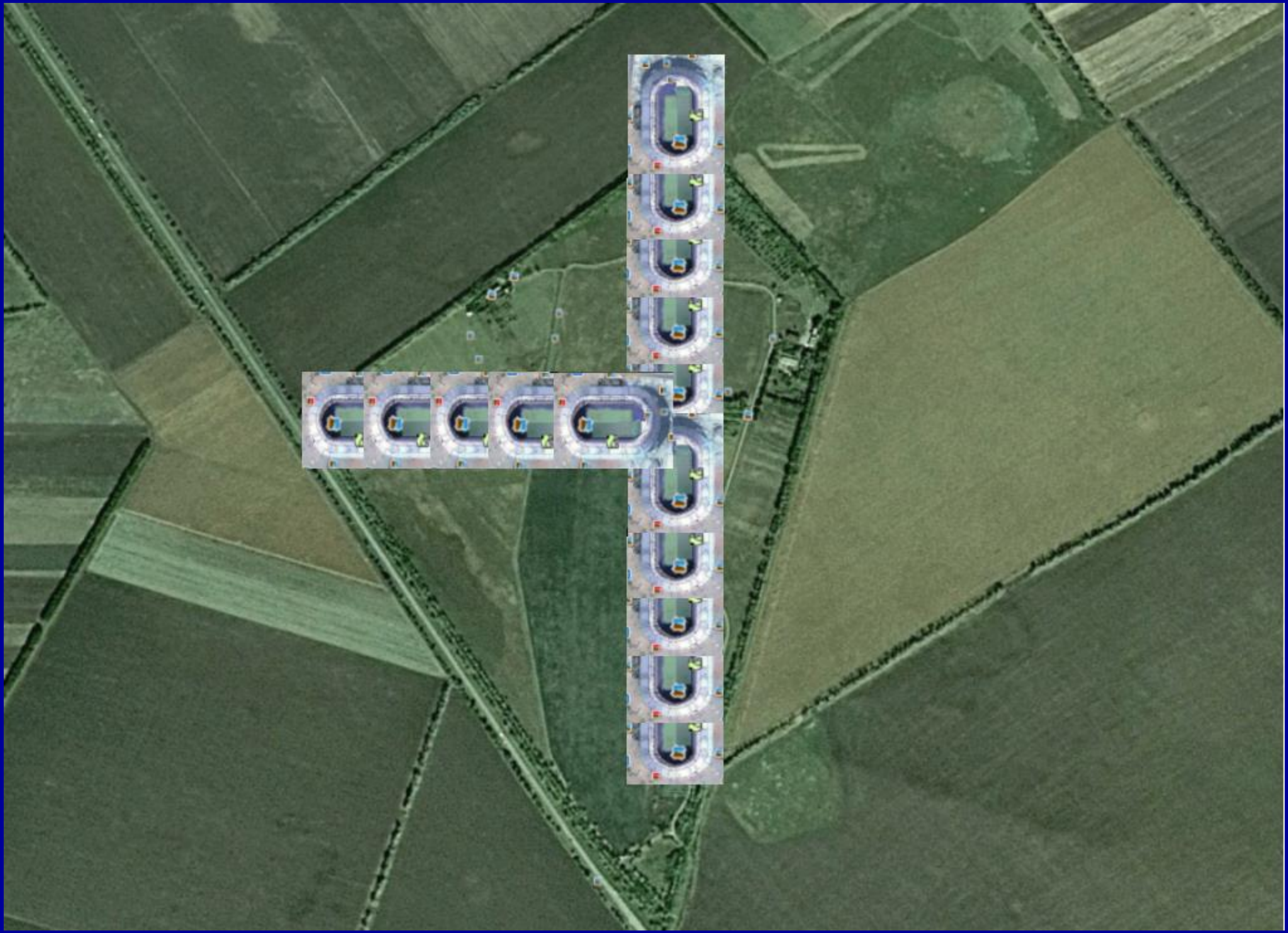
http://ri.kharkov.ua/prosvirn/

UTR-2: Sizes are still incredible! > 1/7 km^2



http://ri.kharkov.ua/prosvirn/

15 football grounds !



http://ri.kharkov.ua/prosvirn/

Basic parameters of UTR-2

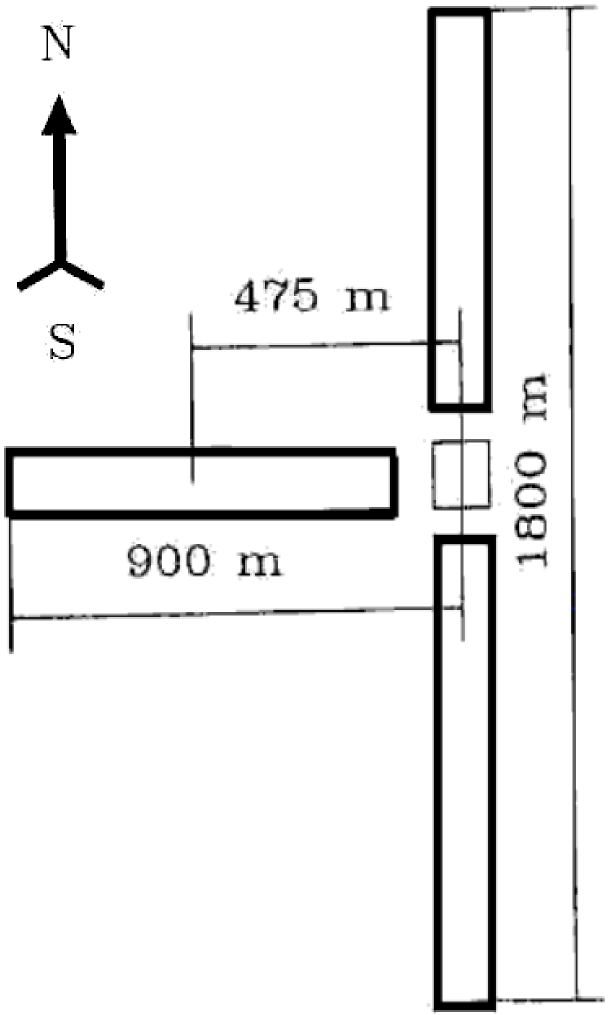


TABLE I-1
The main UTR-2 technical features

Parameters	N-S array	E-W array	Multiply mod
Dimension (m)	1800*54	900*45	1800*1800
Number dipoles	240*6 = 1440	100*6 = 600	–
Effective area (m^2)	93000	45000	130000
Frequency range (MHz)	8 - 40	8- 40	8 - 40
Frequency bands	3	3	3
Three-band amplifiers	104	24	129
Beam width (25MHz), deg	0.4*13	0.8*15	04*0.4
Number beams	5 or 8	1	5
Beam position	2048*16	1024*16	2048*1024
Section	8	4	–
Switched phasing units	313	125	439
Switched delays (km)	16.6	5.9	22.8
Connective delays (km)	68.1	27.4	96.4

E. P. ABRANIN, Yu. M. BRUCK, V. V. ZAKHARENKO & A. A. KONOVALENKO

http://ri.kharkov.ua/prosvirn/

Decameter radio interferometer URAN

http://ri.kharkov.ua/prosvirn/

URAN

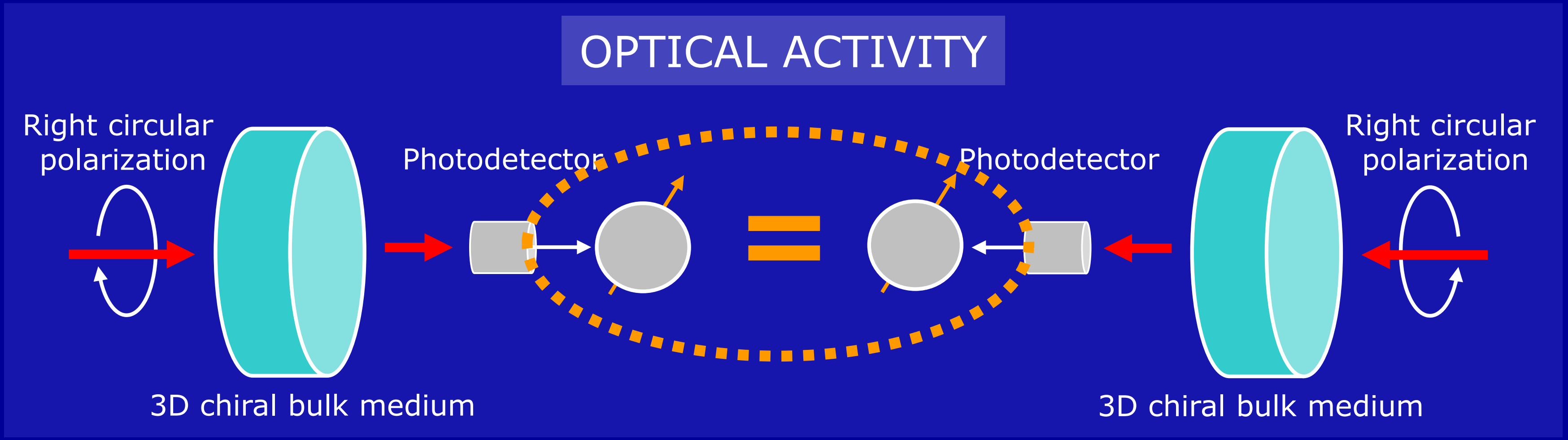
URAN-1…URAN-4 radio telescopes

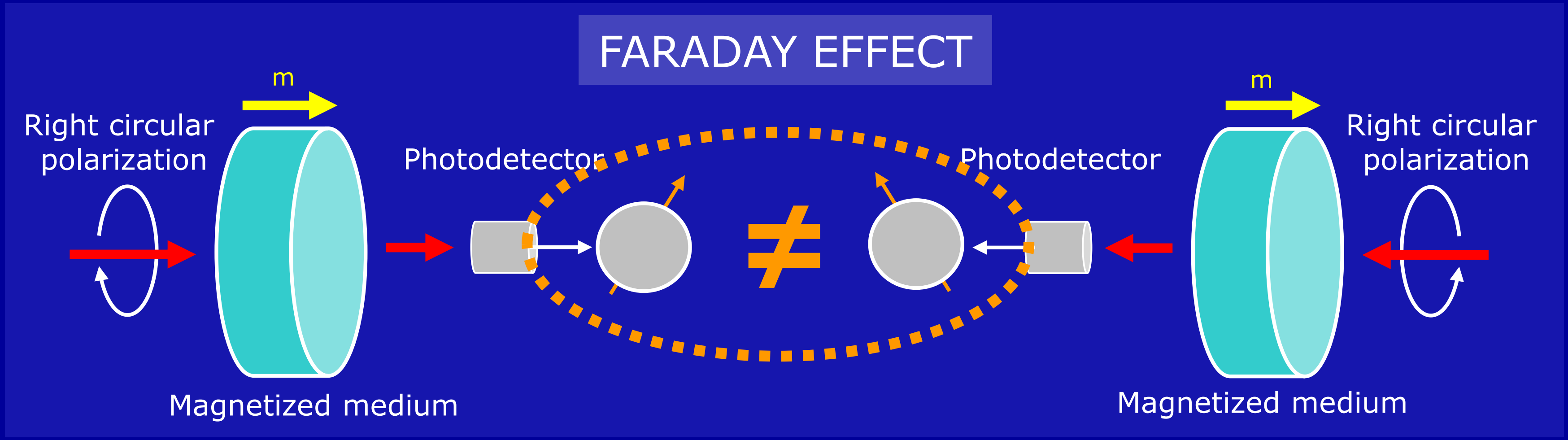
http://ri.kharkov.ua/prosvirn/

Non-stop modernizations of the UTR-2

http://ri.kharkov.ua/prosvirn/

Chirality and Polarization





http://ri.kharkov.ua/prosvirn/

History: Optical activity (1811)

- In classical optics, a phenomenon of optical activity has been a well-known since the early 19-th century, from the studies of Biot (1774-1862), Arago (1786-1853), and Fresnel (1788-1827).
- Somewhat later, Pasteur (1849) showed that the optical activity results from the handed structure of the material. Honoring his work, a chiral medium carries the name, Pasteur medium.

History: Microwaves – Millimeter waves (1898)

- Jagadish Chunder Bose (1858 – 1937) was a great experimental physicist from Calcutta, India.
- J.C.Bose “On the rotating of plane of polarization of electric waves by a twisted structure”, Proc. of the Royal Society of London, vol. 63, 1898, pp. 146 – 152.

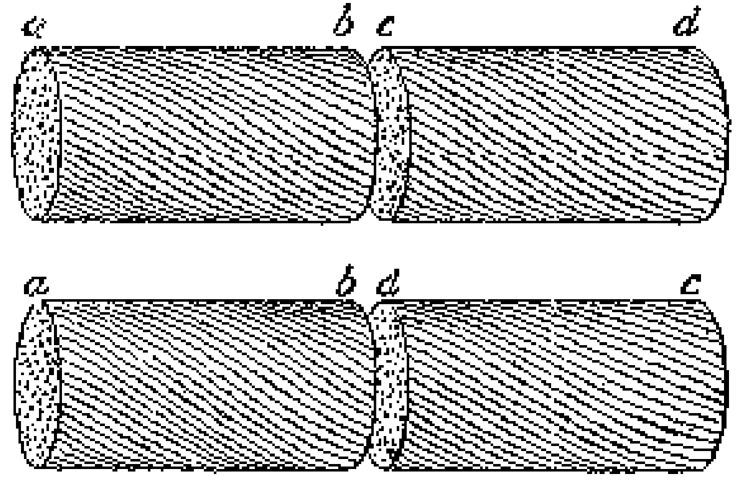
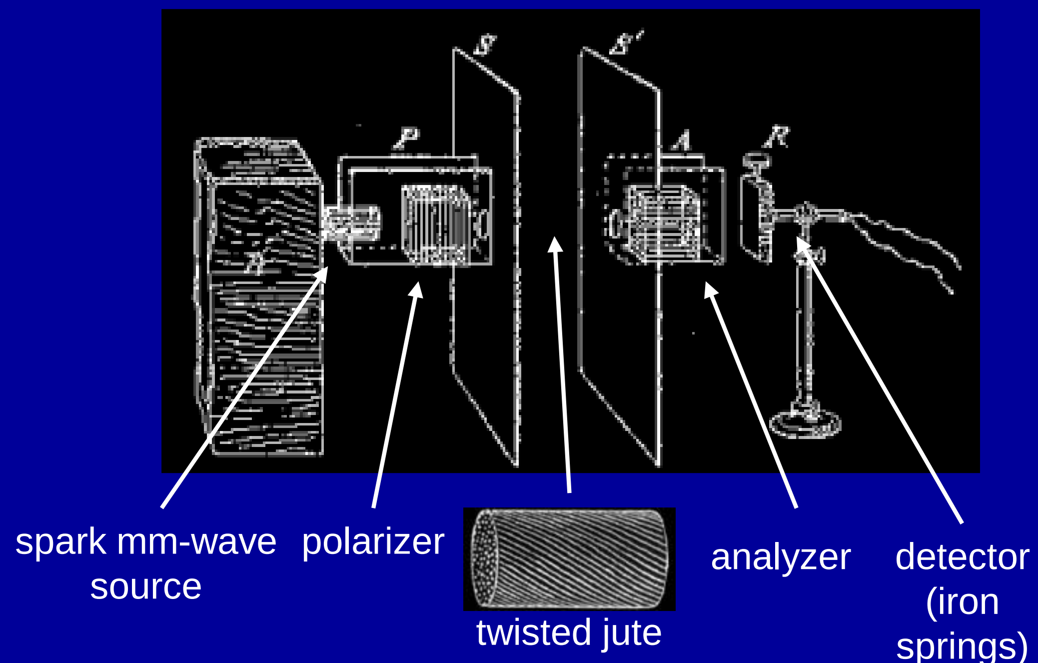


FIG. 2.—Jute elements.

J. Bose's experiment (1898)

”In order to imitate the rotation by liquids like sugar solutions, I made elements of ”molecules” of twisted jute, of two varieties, one kind being twisted to the right (positive) and the other twisted to the left (negative)…”



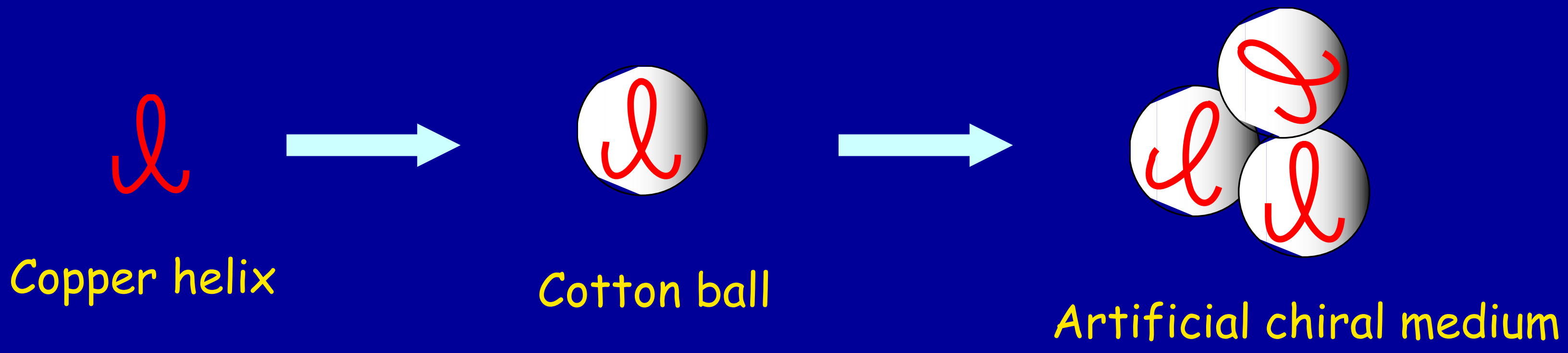
“The twisted structure [of jute] produces an optical twist of the plane of polarization”

Bose, Proc. Royal Soc. of London, **63**, 146 (1898)

http://ri.kharkov.ua/prosvirn/

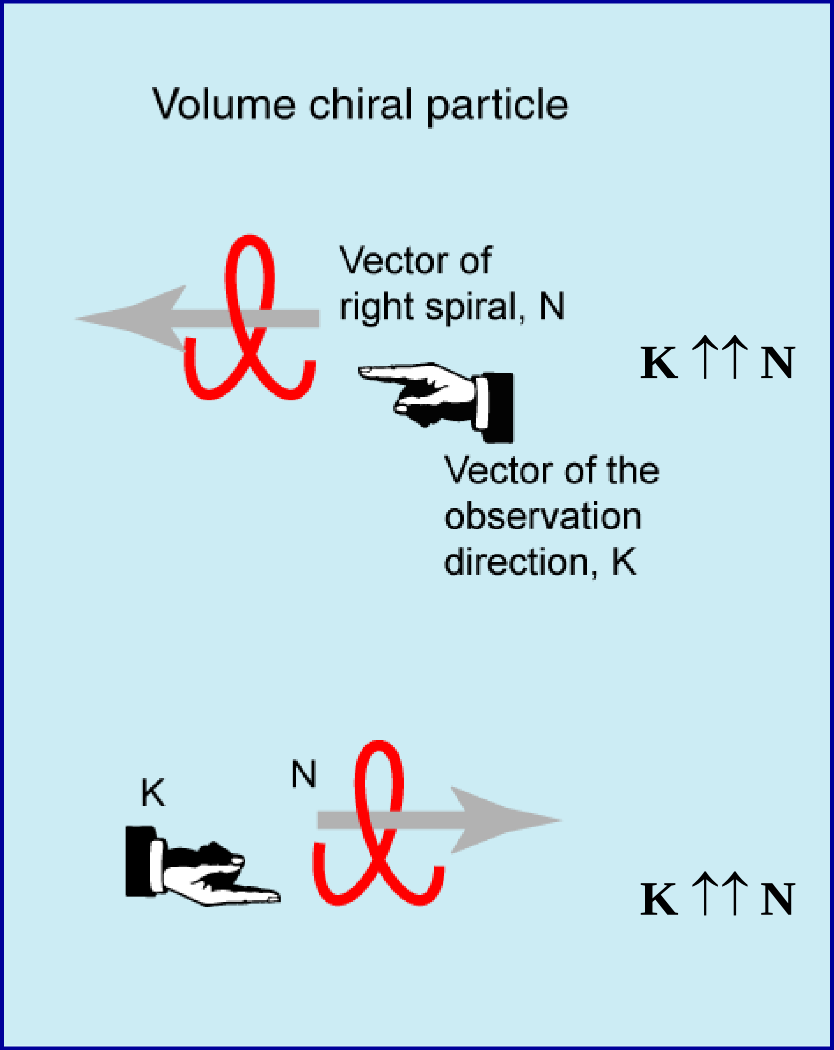
History: First Artificial Chiral Medium in Microwaves (1914)

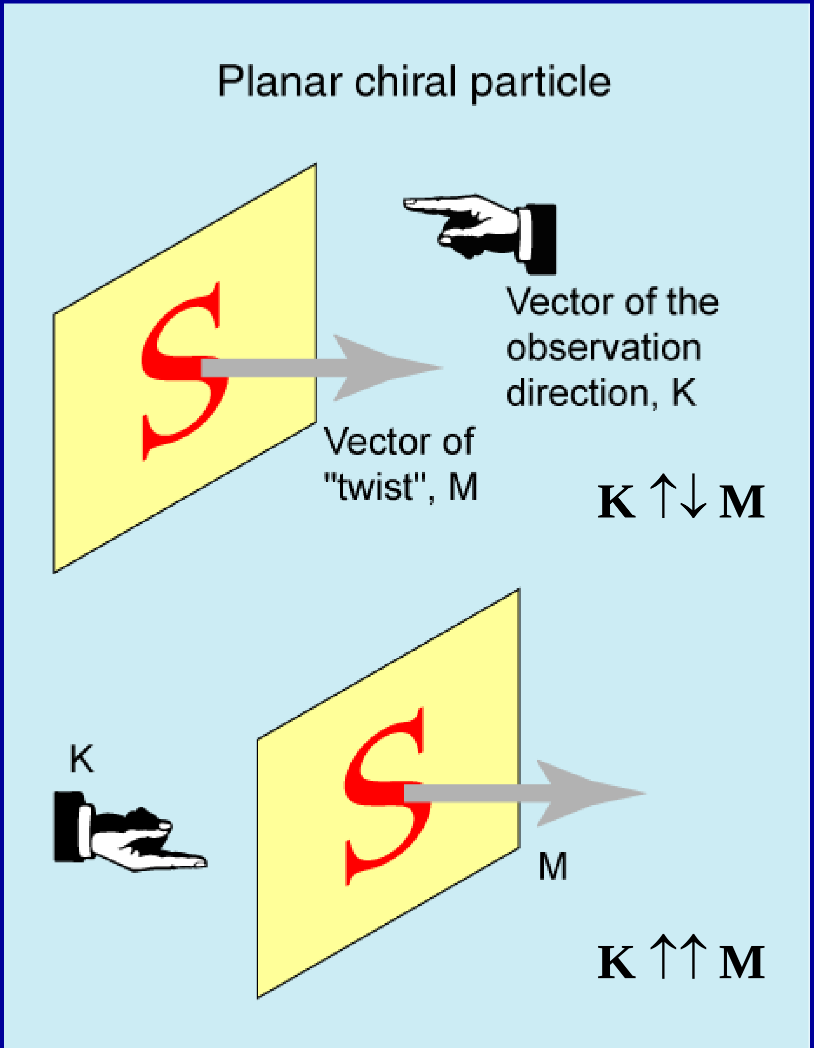
- Karl Ferdinand Lindman (1874 – 1952) was a pioneer in chiral study of an artificial medium. He was with the Helsinki University.
- Lindman synthesized a chiral medium by coiling small helices from copper wire, immersing these in cotton balls, and then positioning these in cardboard box with random orientations.



http://ri.kharkov.ua/prosvirn/

Volume chirality and planar chirality



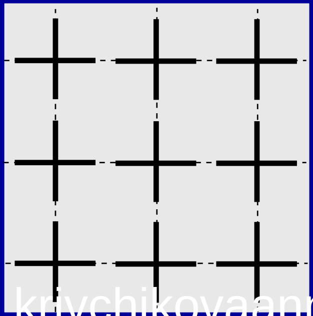


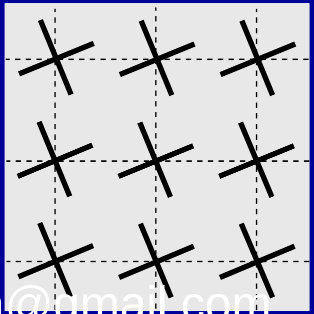
http://ri.kharkov.ua/prosvirn/

Planar chiral arrays

Arrays of straight crosses

Non-chiral array



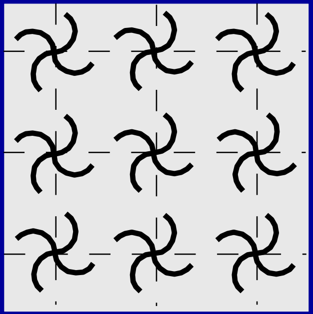


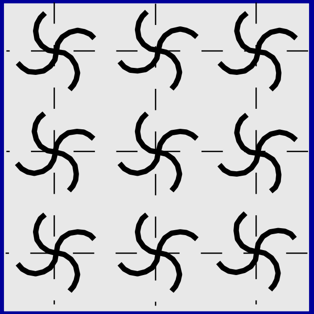
Structural chirality due to array arrangement

$\psi \neq 0, \pi/4, \pi/2$

Arrays of chiral-shaped particles

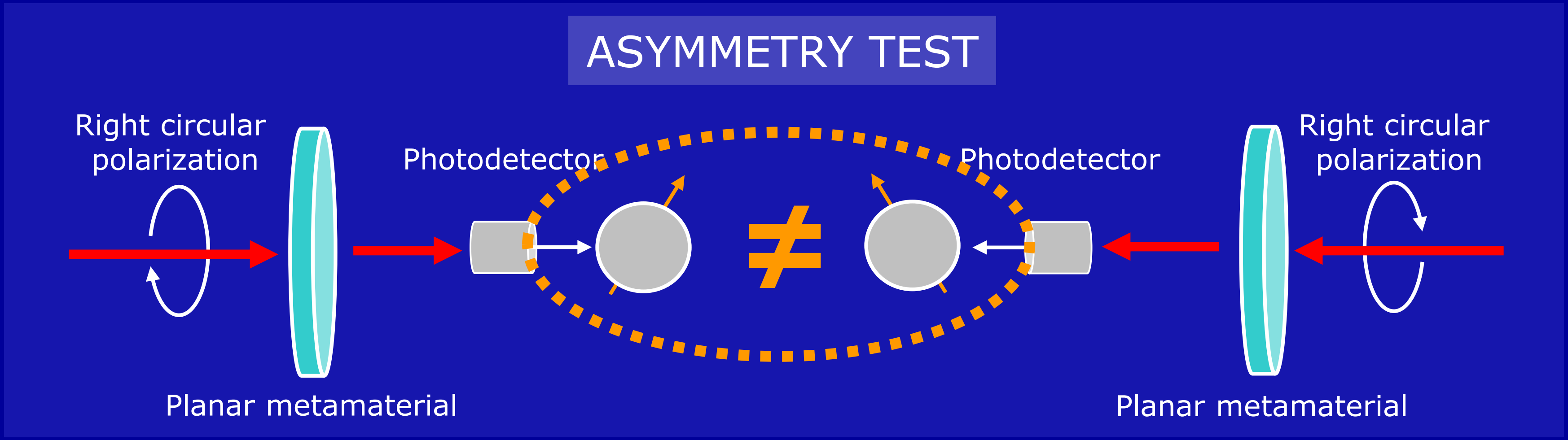
Left-handed gammadions

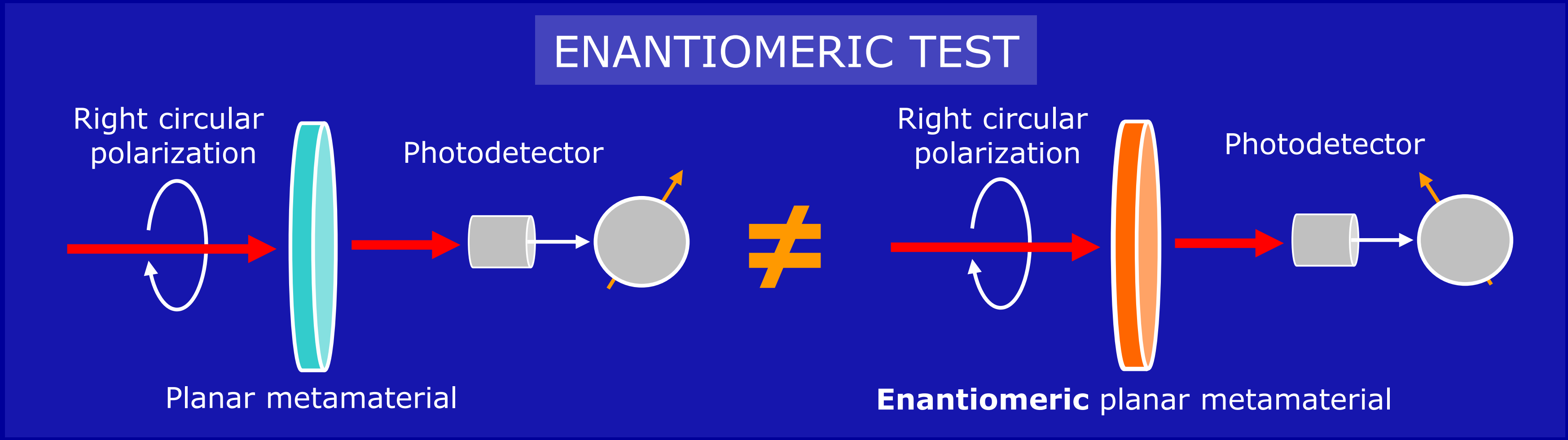




Right-handed gammadions

Chirality and Polarization – Asymmetric Transmission in Metamaterials?



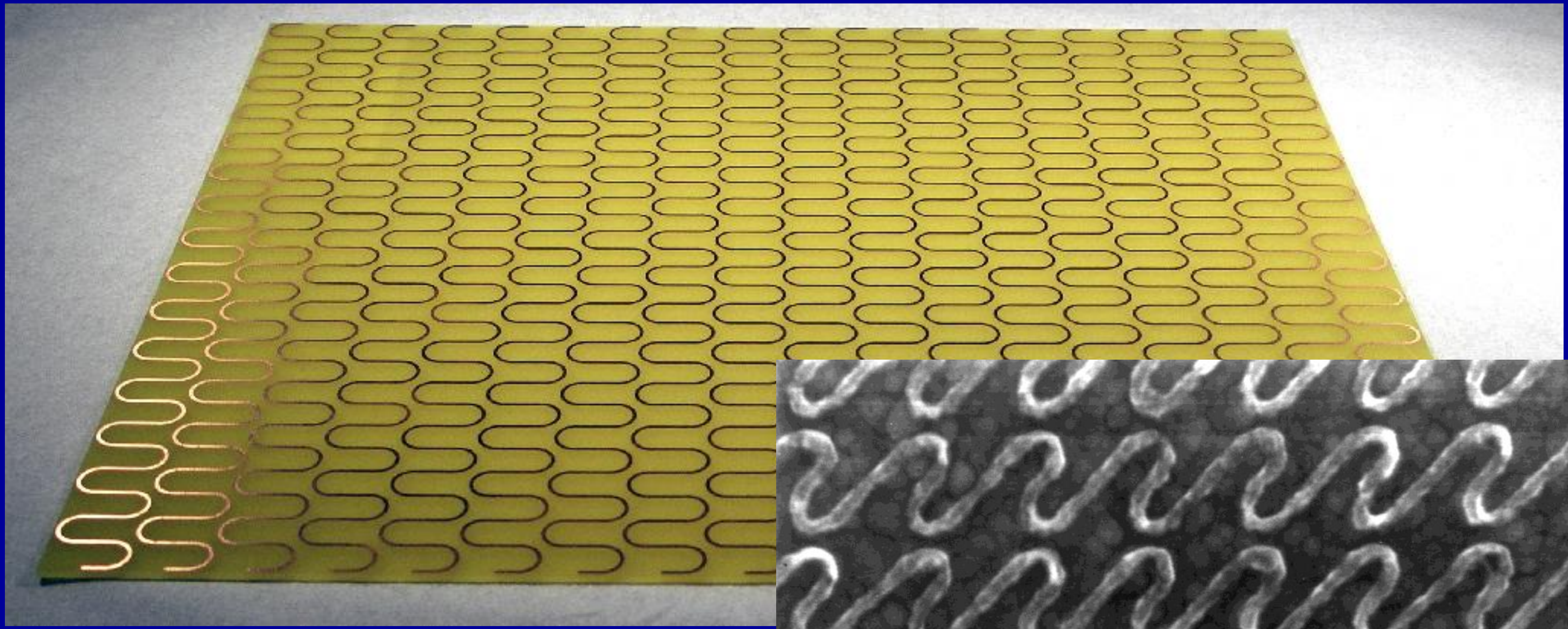


http://ri.kharkov.ua/prosvirn/

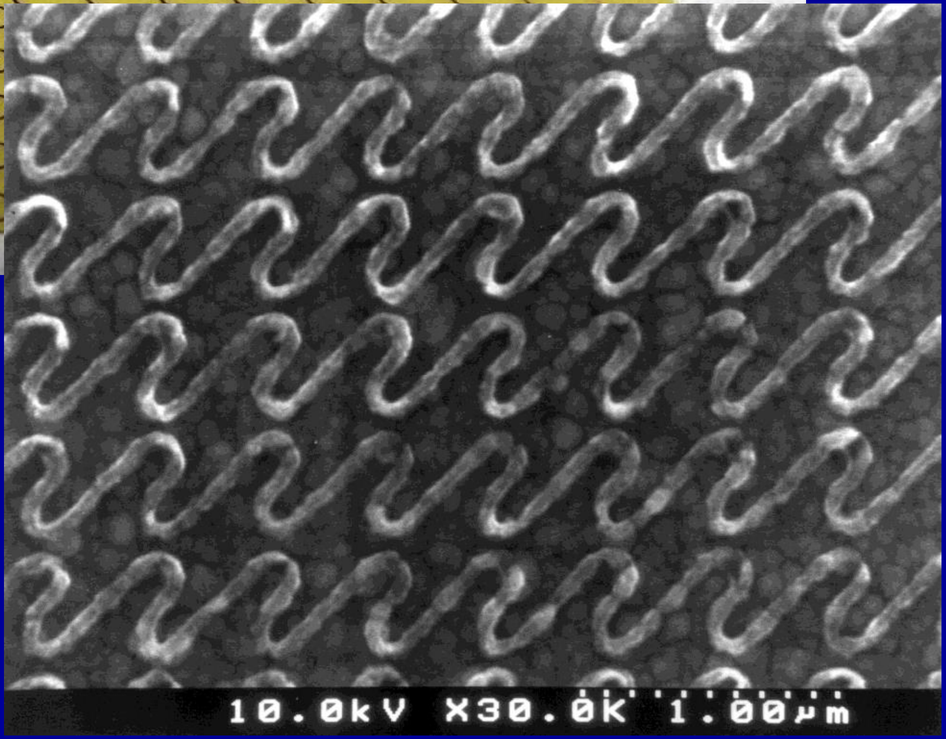
First references on planar chirality

- L. Hecht, L. Barron, Rayleigh and Raman optical activity from chiral surfaces, Chemical Physics Letters, 1994, 225 (4-6), pp. 525-530.
- L. Arnaut, L. Davis, On planar chiral structures, Progress in Electromagnetic Research Symposium (PIERS 1995), Seattle, WA, p. 165.
- L. Arnaut, Chirality in multi-dimensional space with application to electromagnetic characterization of multi-dimensional chiral and semi-chiral media, J. Electrom. Waves and Applications, 1997, vol. 11, pp. 1459-1482.

Fish-Scale periodic structures



Microwave array



Optical chiral array. Aluminium pattern placed on silica substrate. Pitch is 440 nm.

http://ri.kharkov.ua/prosvirn/

Microelectronic Engineering 86 (2009) 1081–1084

Contents lists available at ScienceDirect

Microelectronic Engineering

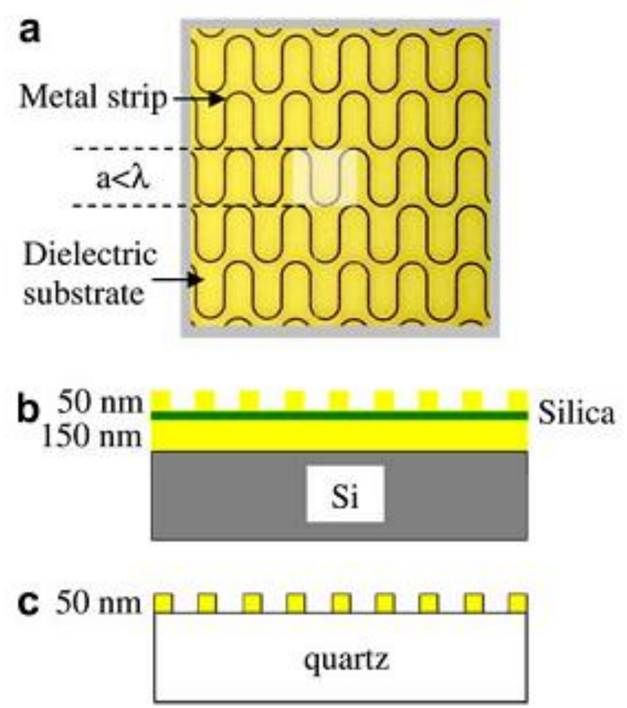
journal homepage: www.elsevier.com/locate/mee

Electron beam lithography for high density meta fish scale operational at optical frequency

Yifang Chen [a,*], Alexander S. Schwanecke [b], V.A. Fedotov [b], V.V. Khardikov [b], P.L. Mladyonov [b], S.L. Prosvirnin [b], A.V. Rogacheva [b], Nikolay I. Zheludev [b], Ejaz Huq [a]

[a] Micro and Nanotechnology Centre, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, UK

[b] EPSRC NanoPhotonics Portfolio Centre, School of Physics and Astronomy, University of Southampton, High



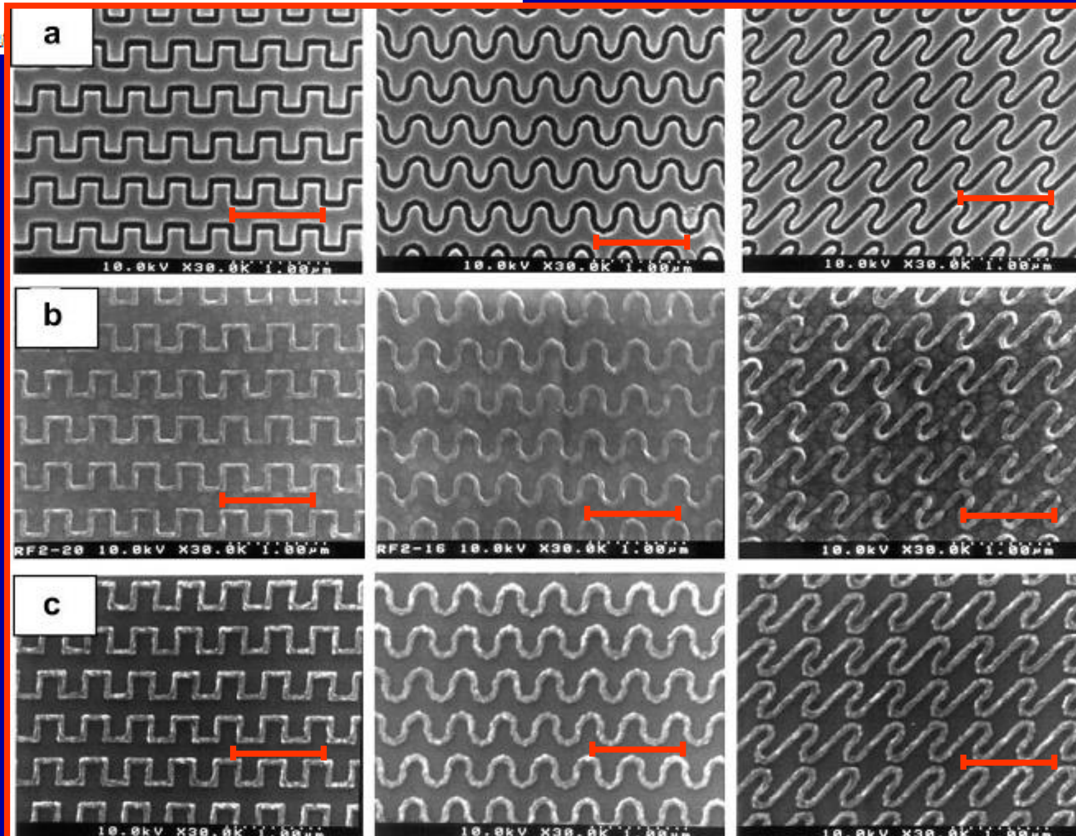
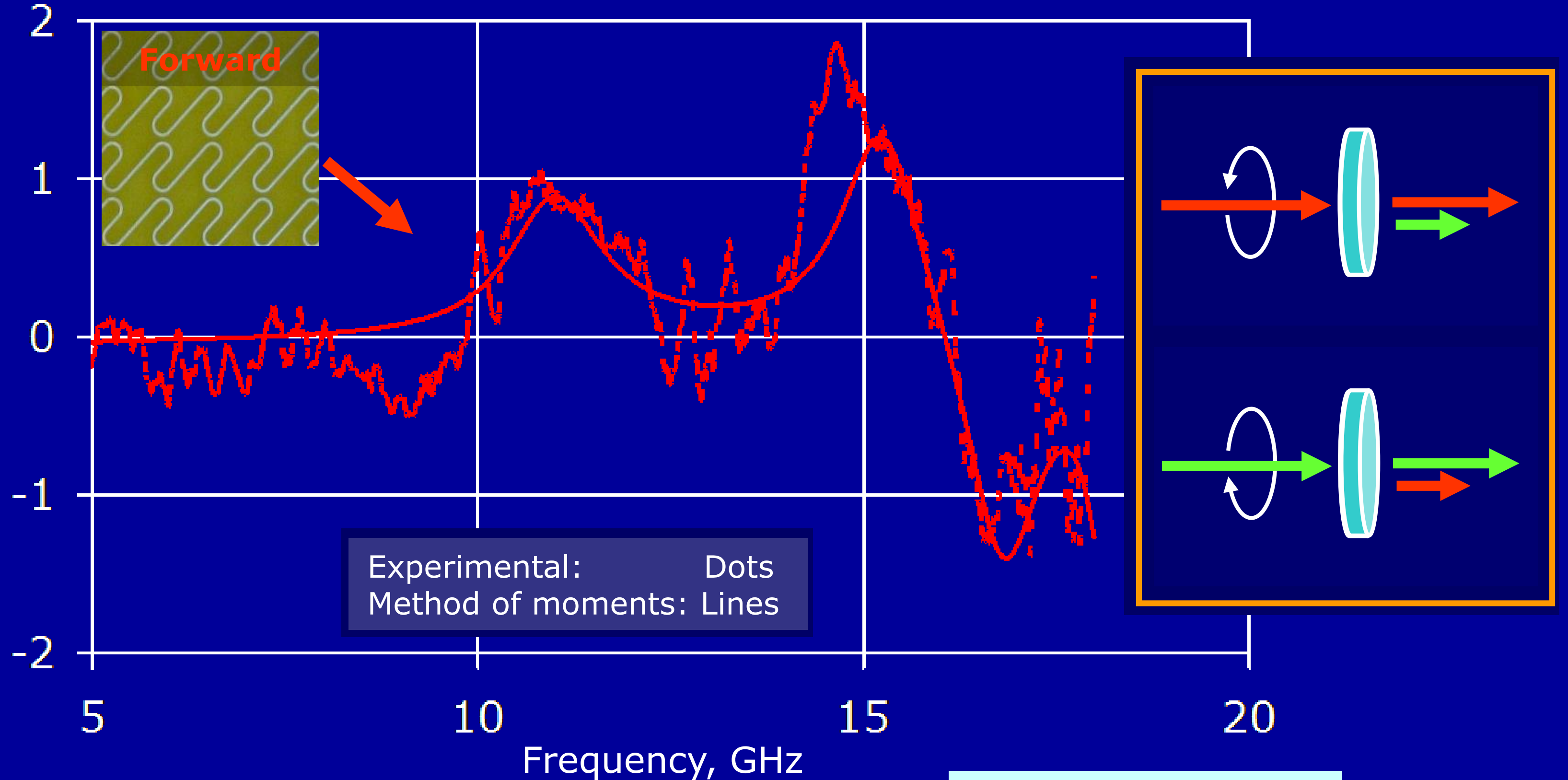


Fig. 4. Nano fish scale patterns in (a) resist, (b) on silicon/Al with reflective mirror and (c) on quartz with transparent mode.

http://ri.kharkov.ua/prosvirn/

Asymmetry in Microwave Domain

Polarization Conversion Difference for Opposite Circular Polarizations

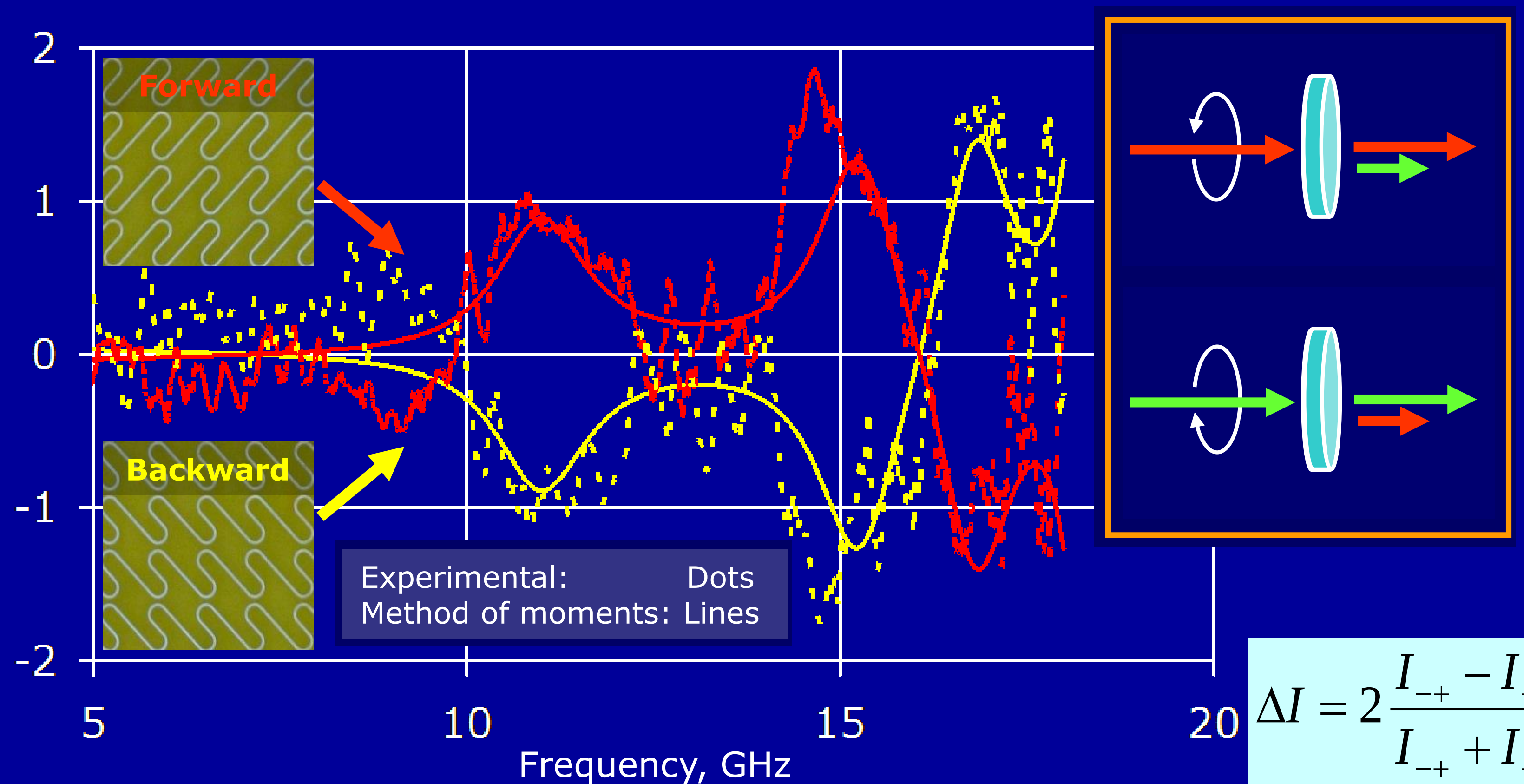


$$\Delta I = 2\frac{I_{-+} - I_{+-}}{I_{-+} + I_{+-}}$$

http://ri.kharkov.ua/prosvirn/

Asymmetry in Microwave Domain – Main Experimental Results

Polarization Conversion Difference for Opposite Circular Polarizations

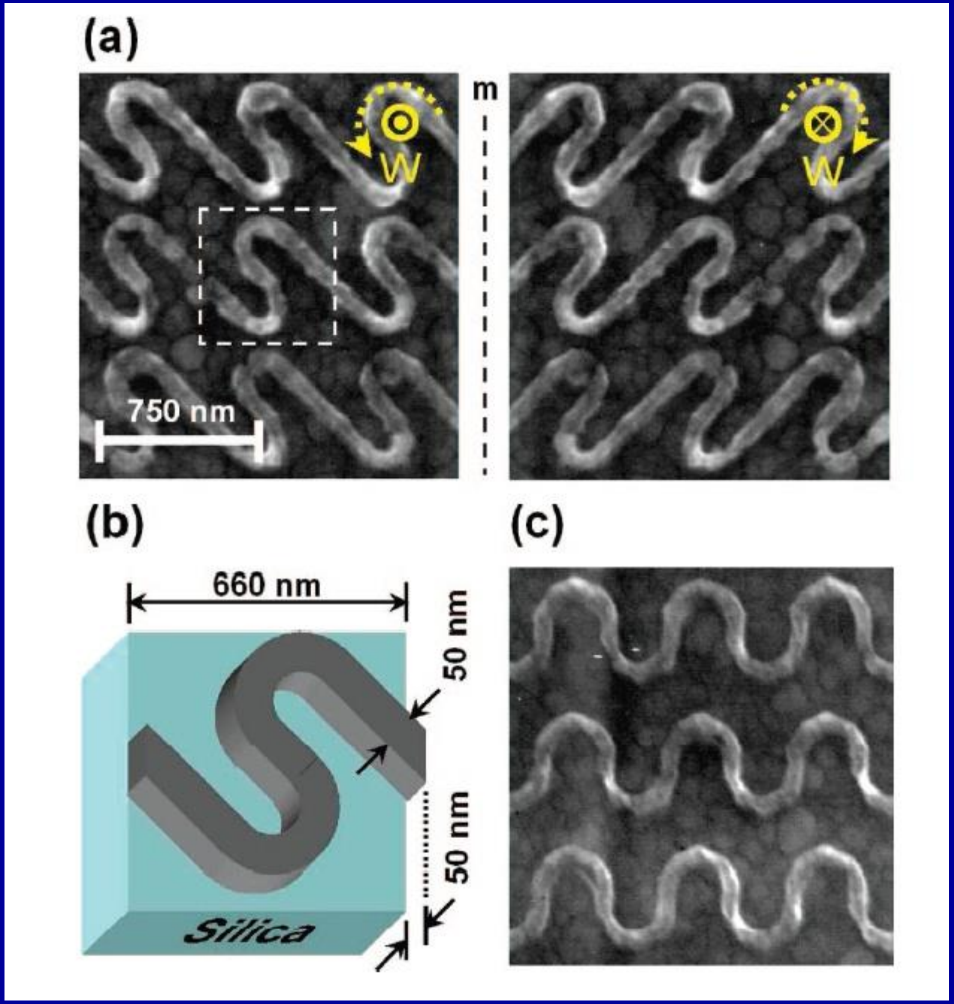


$$\Delta I = 2\frac{I_{-+} - I_{+-}}{I_{-+} + I_{+-}}$$

Fedotov, Mladyonov, Prosvirnin, Rogacheva, Chen, and Zheludev
Phys. Rev. Lett. 97, 167401 (2006)

http://ri.kharkov.ua/prosvirn/

Enantiomeric sensitive plasmon resonance in planar chiral meta-material

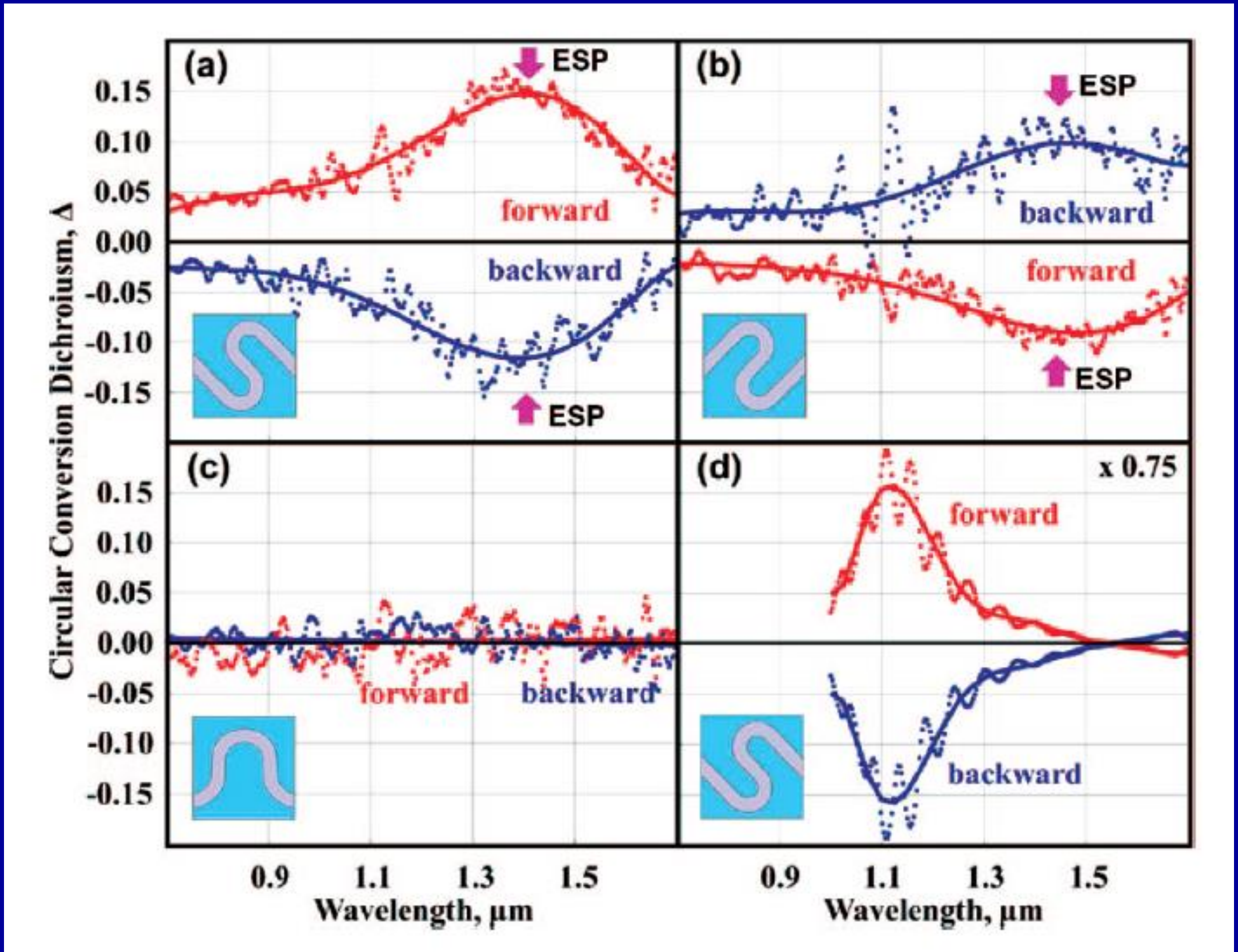


Theory:

Fedotov, Schwanecke, Zheludev, Khardikov, & Prosvirnin
Nano Letters, 2007, vol. 7, no. 7, pp. 1996-1999

http://ri.kharkov.ua/prosvirn/

Enantiomeric sensitive plasmon resonance in planar chiral meta-material

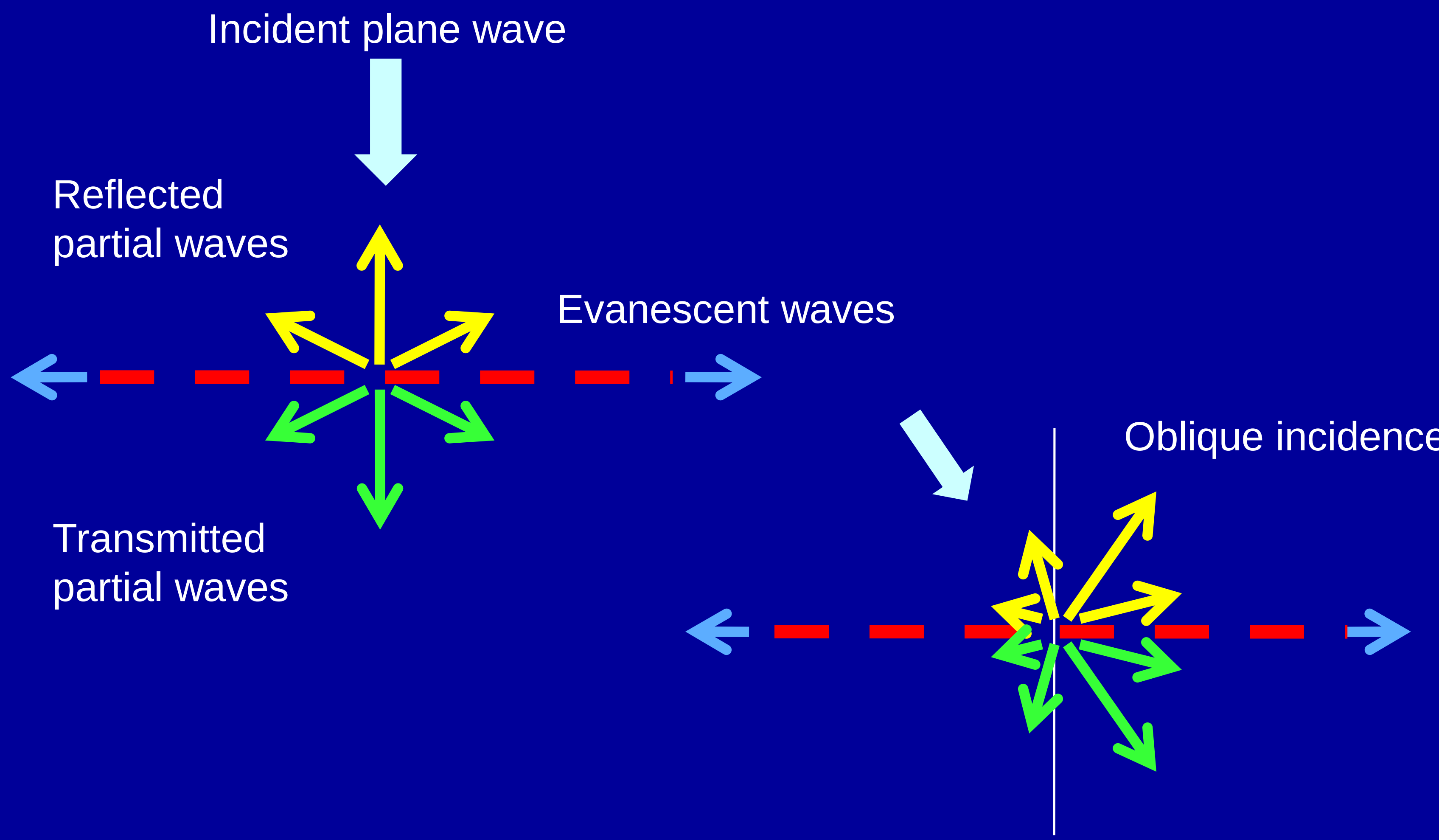


$\Delta = 2(T_+ - T_-)/(T_+ + T_-)$

Schwanecke, Fedotov, Khardikov, Prosvirnin, Chen, Zheludev, *Nano Letters*, 2008, vol. 8, no. 9, pp. 2940-2943

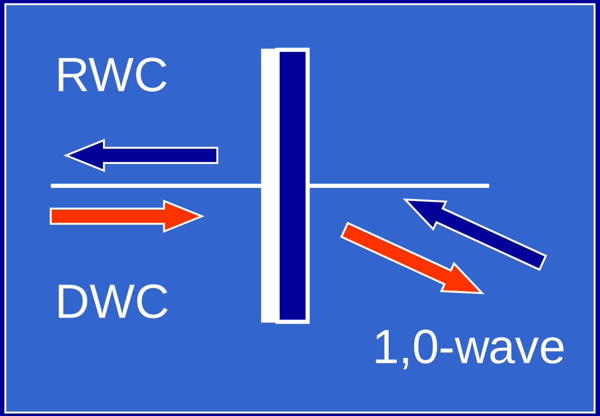
http://ri.kharkov.ua/prosvirn/

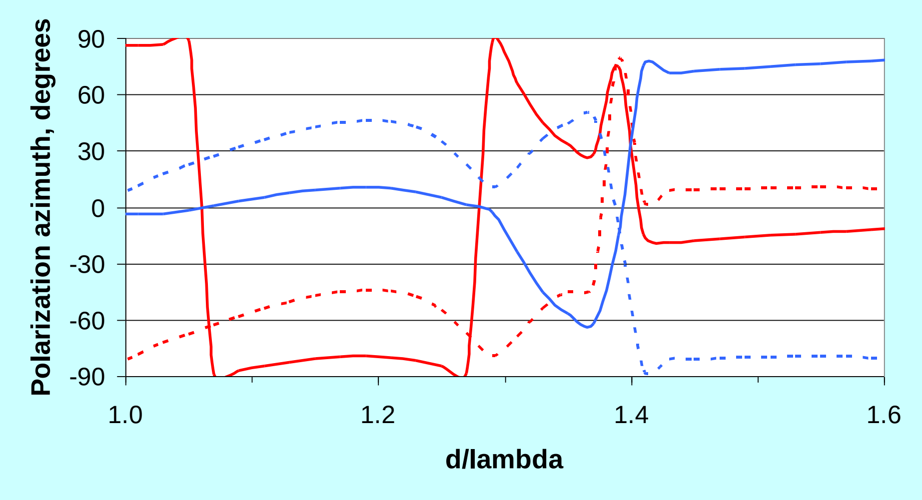
Diffraction partial waves (diffraction orders)

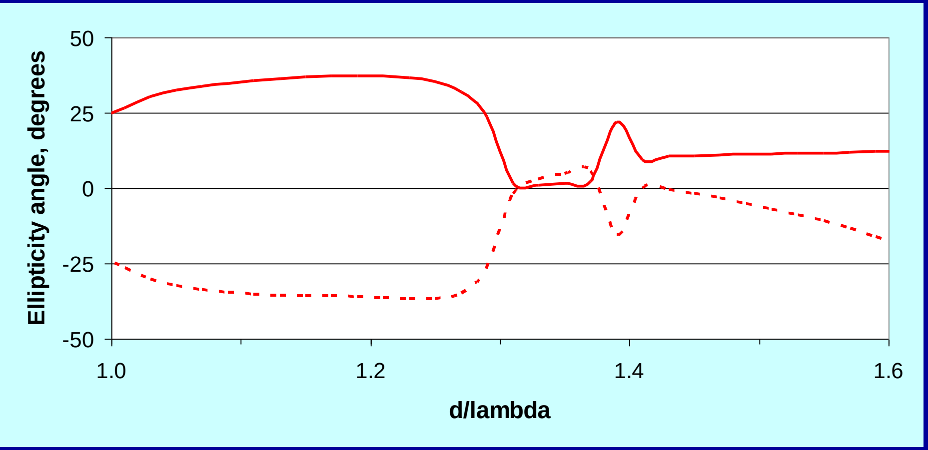


http://ri.kharkov.ua/prosvirn/

Frequency dependencies of azimuths and ellipticity angles of polarization eigenstates of DWC and RWC with (1,0)-diffraction wave







Ellipticity angles of RWC have opposite signs in compare with their values in DWC.

http://ri.kharkov.ua/prosvirn/

Prosvirnin, Zheludev
J. Opt. A: Pure Appl. Opt., 2009, vol. 11, 074002 (10pp).

Summary

Planar Chiral Metamaterials

Microwaves and optical asymmetric transmission

Polarization eigenstates are biorthogonal for waves diffracting by array in the opposite directions