Planar Goubau Lines

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Although we can observe an emergence of free-space THz sources and detectors enough powerful to enable the diffusion of metrology systems based of THz free-space radiation in many applications, the guided-wave THz is still an emerging field: there is not some THz-suited solutions equivalent to the optic fiber in optics side or coaxial cable in electronics side. Rectangular waveguides are efficient and allow great confinements [1] but there are expensive due to the very tricky mechanically fabrication because the slit which propagating the wave becomes very small when the frequency increases, moreover the alignment between devices is delicate and it do not facilitate the setting-up of applications especially when flexibility and spatial integration are needed. An alternative way to transport THz waves is to use some so-called "on-chip" waveguides which there extremely compact because they are defined by lithography technique, moreover they are intrinsically suited to be integrated into microelectronics applications. There we can find the planar waveguide with a complicated fabrication process including several metallization steps. The coplanar waveguide (CPW) should be a great waveguide but there is often non-desired mode appearance which can be corrected by processing a difficult setting-up of an air-bridge or a via-hole between the two ground-plans, and finally the Planar Goubau Line (PGL) which the development is the main subject of our project.

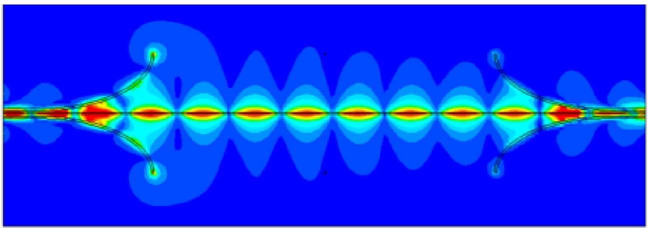

Figure 1: Electric field @ 500GHz

The PGL is a very attractive on-chip THz single wire transmission line which allows TEM propagation on a single conductor [2] with a sub-wavelength transverse confinement [3][4], the excitation is based on an EM transition between a CPW and the PGL as shown on fig. 1 & 2, the electromagnetic Goubau mode is a collective oscillation of electrons on the planar interface between the metallic wire and the dielectric substrate [5].

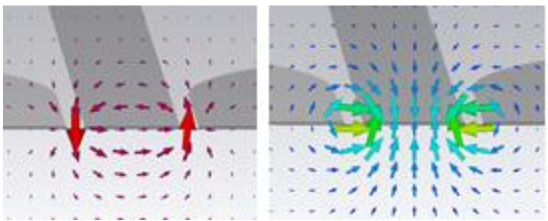

Figure 2: Magnetic (left) & electric (right) fields on the Goubau mode excitation

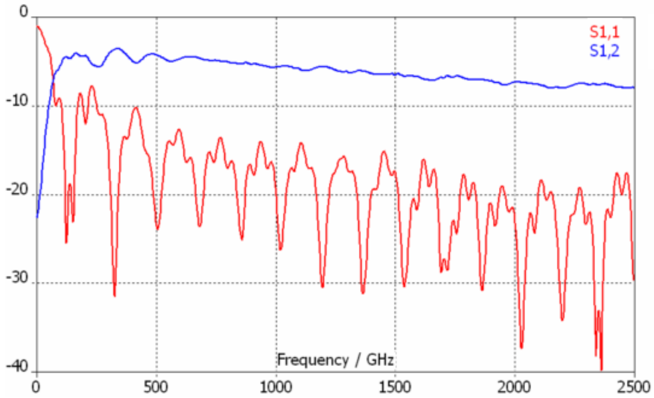

Figure 3: S-parameters of a 3mm long PGL section

This membrane topology gives a clearly broadband behavior in transmission as we can see on fig. 3, moreover we can design some filtering functions by corrugating the line (fig. 4), we can also design low-loss bend in order to increase the structure's adaptability and cancelling the direct coupling between the two CPW's, results on figure 5. An important point is that the structure is scalable in order to transpose the all properties in different ranges of the spectrum [6].

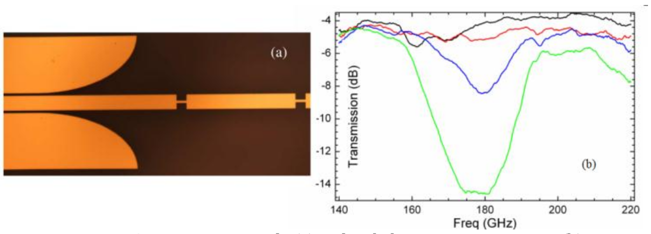

Figure 4: Corrugation example (a) and its behavior in transmission (b).

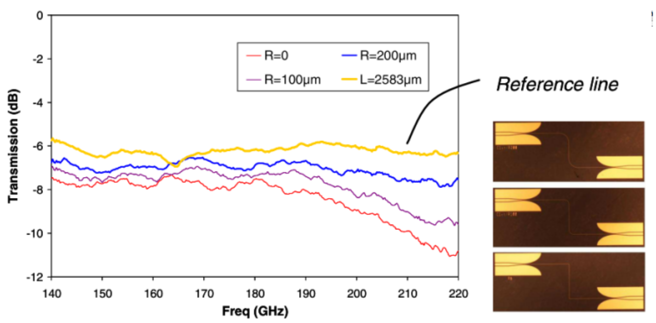

Figure 5: Bending measurement results with different radius of curvature.

There are also results on placing Split Ring Resonators (SRR) on each side from the Goubau Line (fig. 6), these SRR are intended to absorb energy only on the PGL and yielding narrow-band resonances [6], an especially interesting perspective consist in including a transistor between the 2 capacity gaps of the coupled SRR's in order to shunt them, in this way the absorbing effects are canceled as well as filtering functions, as shown on figure 7. Then we can decide to incorporate an assortment of different sizes of SRR which are yielding different narrow-bands resonances on a broadband transmission spectrum, by a selective shunting this kind of structure should have a large dynamic range in transmissibility which can be useful for high-bandwidth THz communication application.

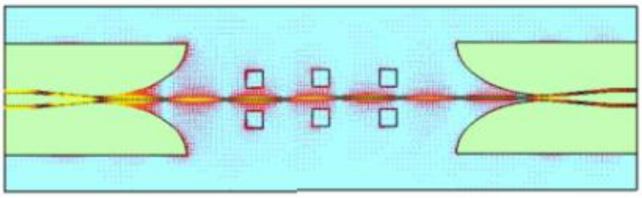

Figure 6: Electric field coupling between PGL and SRR's.

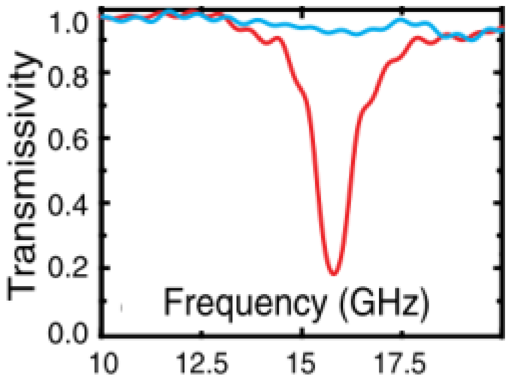

Figure 7: PGL experiment results in transitivity with classic SRR on redline, and shunted on blueline.

The 2nd application field of this structure concerns the biological characterization; although there are running-up THz investigations on biological entities by using free space spectroscopy of gas or solid phase [7][8], in return there is a great demand of biologist concerns the investigations on liquid phase where THz radiations are strongly absorbed except if we work on very small volume, thus integrating confined-fields THz functions inside microfluidics circuits seems to be a promising way [9][10][11].

The 3rd application field concerns near-field THz microscopy, indeed one the most common technique used today (SNOM, see fig. 8) [12] requires powerful incident THz radiations released by a non-tunable source (THz laser, or QCL into low temperatures …), then the information of the sample is included in the very small part of reflected tip-scattered radiations which are drowned into the useless non-scattered reflected radiations, thus the signal to noise ratio (SNR) is very low [13] and this brings a lot of difficulties. The idea is to use the PGL as a sweeping-tip, the evanescent-field interaction will give the information [13], and the SNR should be very improved because a much bigger part of the "incident" radiations should interacts with the sample before during the reflection. Experiment will be easier because we could just exciting the PGL with a VNA, and treating the S-parameters cartography.

A big part of the project will be devoted to electromagnetic simulation with CST microwave studio, achievements lithographic steps and can be performed.

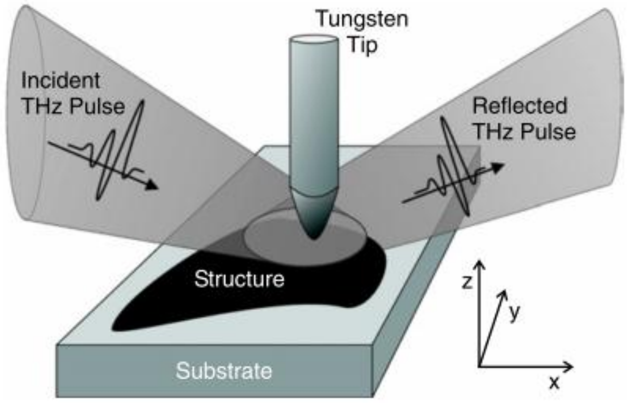

Figure 8: Schematic of the SNOM head.

[1] Gacemi, D., Mangeney, J., Blary, K., Lampin, J.-F., Laurent, T., Akalin, T., Crozat, P., et al. (2012). Confinement of THz surface waves on the subwavelength size metal waveguide. *Applied Physics A*, 993–995. doi:10.1007/s00339-012-7363-y

[2] "terahertz pulses along planar Goubau lines," no. May 1962, p. 4244, 2006.

[3] Gacemi, D., Mangeney, J., Blary, K., Lampin, J.-F., Laurent, T., Akalin, T., Crozat, P., et al. (2012). Confinement of THz surface waves on the subwavelength size metal waveguide. Applied Physics A, 993–995. doi:10.1007/s00339-012-7363-y

[4] J. Emond, M. Grzeskowiak, S. Protat, G. Lissorgues, F. Deshours, E. Richalot, and O. Picon, "Ligne de Goubau planaire faibles pertes sur Silicium haute résistivité à 60GHz," pp. 3–4, 2011.

[4bis] Gacemi, D., Mangeney, J., Laurtent, T., Lampin, J.-F., Akalin, T., Blary, K., Degiron, a, et al. (2012). THz surface plasmon modes on planar Goubau lines. Optics express, 20(8), 8466–71. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22513554

[5] Gacemi, D., Mangeney, J., Blary, K., Lampin, J.-F., Laurent, T., Akalin, T., Crozat, P., et al. (2012). Confinement of THz surface waves on the subwavelength size metal waveguide. Applied Physics A, 993–995. doi:10.1007/s00339-012-7363-y

[6] S. W. Smye, J. M. Chamberlain, A. J. Fitzgerald, and E. Berry, "The interaction between Terahertz radiation and biological tissue", Phys. Med. Biol., vol. 46, no. 9, pp.101 -112 2001

[7] P. H. Siegel, "Terahertz technology in biology and medicine", IEEE Trans. Microw. Theory Tech., vol. 52, no. 10, pp.2438 -2447 2004

[8] G. R. Facer, D. A. Notterman, and L. L. Sohn, "Dielectric spectroscopy for bioanalysis: From 40 Hz to 26.5 GHz in a microfabricated wave guide", Appl. Phys. Lett., vol. 78, no. 7, pp.996 -998 2001

[9] M. Nagel, F. Richter, P. Haring-Bolivar, and H. Kurz, "A functionalized THz sensor for marker-free DNA analysis", Phys. Med. Biol., vol. 48, pp.3625 -3636 2003

[10] J. Hefti, A. Pan, and A. Kumar, "Sensitive detection method of dielectric dispersions in aqueous-based surface-bound macromolecular structures using microwave spectroscopy", Appl. Phys. Lett., vol. 75, no. 12, pp.1802 -1804 1999

[11] Keilmann, F. (2009). Viewing the nanoworld in infrared/THz light. 2009 34th International Conference on Infrared, Millimeter, and Terahertz Waves, 1–4. doi:10.1109/ICIMW.2009.5324706

[12]Kersting, R., Chen, H.-T., Karpowicz, N., & Cho, G. C. (2005). Terahertz microscopy with submicrometre resolution. Journal of Optics A: Pure and Applied Optics, 7(2), S184–S189. doi:10.1088/1464-4258/7/2/024

[13] Cunningham, J., Byrne, M., Upadhya, P. C., Wood, C., Dazhang, L., Lachab, M., Khanna, S. P., et al. (2007). Evanescent-field Terahertz Time-domain, (0), 9–10.