Genetic algorithm optimization of infrared plasmonic absorbers

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***Abstract*- The absorption of a multiband absorber based on a periodical plasmonic grating has been optimized. The optical and geometrical parameters of the plasmonic structure which is composed of germanium and gold are determined by an efficient genetic algorithm. The electromagnetic response of the absorber is numerically obtained by using the frequency domain finite element method. A multiband absorber with near unity absorption in the mid- and long-wave infrared region from 3.5 µm to7 µm has been obtained**.

I. INTRODUCTION

Plasmonic absorbers have been investigated because of a myriad of potential applications such as thermal and image detectors, stealth, filtering and polarizers [1-2]. In addition, multiband infrared detectors have the ability of acquiring the infrared image of objects in two or more infrared spectral bands in this way they can make an efficient use of the information contained in each separate band, consequently, an improvement of the signal recognition can be expected [1]. Multiband spectrum response of infrared detectors can be adjusted by the design of plasmonic or metamaterial structures, one of the approaches uses a trapezoidal grating with two or more resonant wavelength [1] while the other considers periodical arrays of crosses with different sizes [2] and unbalanced superlattices gratings composed of several elements with different widths and heights [3]. On the other hand, the synthesis or inverse design of photonics or plasmonic devices to exhibit a particular electromagnetic behavior is under research and the genetic algorithm is one of the most commonly used for this purpose [5, 6].

II. METHODS

Here, the classical genetic algorithm [4], in conjunction with an efficient frequency domain finite element approach (COMSOL), has been implemented aiming the design of multipeak absorbers in the mid and far infrared region (3300nm – 9800nm). The proposed absorber is composed by two metallic strips over the top of a three-layer dielectric-metal-dielectric, as depicted in Fig. 1. The metal is gold and the dielectric Germanium, the refractive indexes are given in [3].

The genetic algorithm has been implemented with the following parameters: Population of 10 individual with real representation of the variables, a wheel roulette selection, a mutation ratio between 0.0005 and 0.15, a crossing ratio 0.8 to 0.95 preserving the best individual as elitism. The fitness function was defined to optimize a structure with multiple absorption peaks as described in the following pseudocode:

```
1.  idx, properties = find_peaks(absorb)
2.  m_a = mean(absorb[idx])
3.  m_p = mean(properties[‘prominences’])
4.  fitness = m_a + m_p + len(peak_idx) * weight
```

To evaluate the fitness of an individual we must first locate the peaks' locations and their prominences. Lines 2 and 3 of the pseudocode obtain the mean of the absorption at these indexes and the mean of the respective prominences. Next, the fitness value is calculated by an equation where the number of found peaks is multiplied by a weight and then added to variables *m_a* and *m_p*.

Note that the value of variable *weight* dictates the number of peaks and how good they are absorbing the light. If we use a number too low as weight, the genetic algorithm will converge to a structure which absorbance is shown by less peaks with high absorption. When the weight if too high, we will obtain a structure with many but not good peaks of absorption.

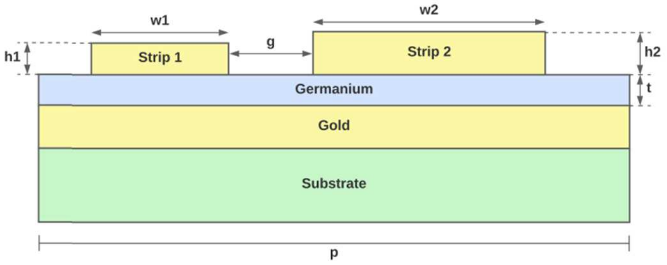

Fig. 1. Schematic of the analyzed absorber with its optical geometrical and optical parameters.

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III. RESULTS

The evolution of the fitness function is shown in Fig. 2. and the absorption spectra is shown in Fig. 3 with the optimized parameters: p=2139nm, t=111nm, w1=383nm, h1=117nm, g=335nm, w2=531nm and h2=69nm. The absorption peaks for TM polarization are located at the wavelengths of 3762nm, 4911nm and 6226nm, respectively, with absorption values of 0.993, 0.997 and 0.999, respectively. The spatial field distribution at the resonant wavelengths are shown in Fig. 5.

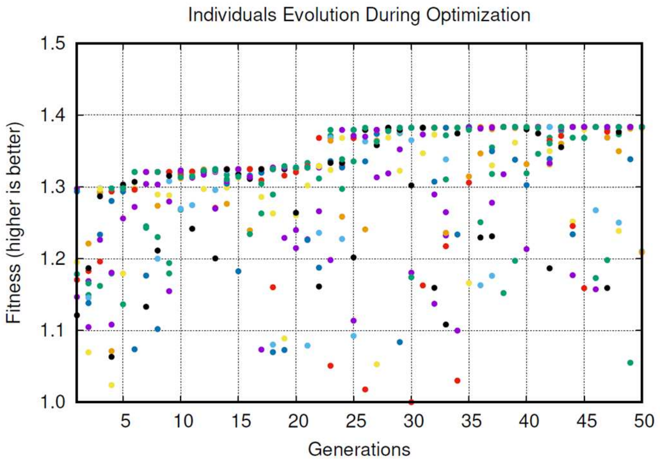


Fig. 2.Evolution of the fitness

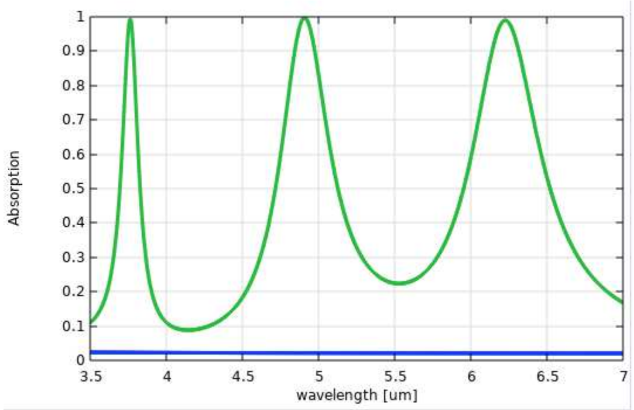
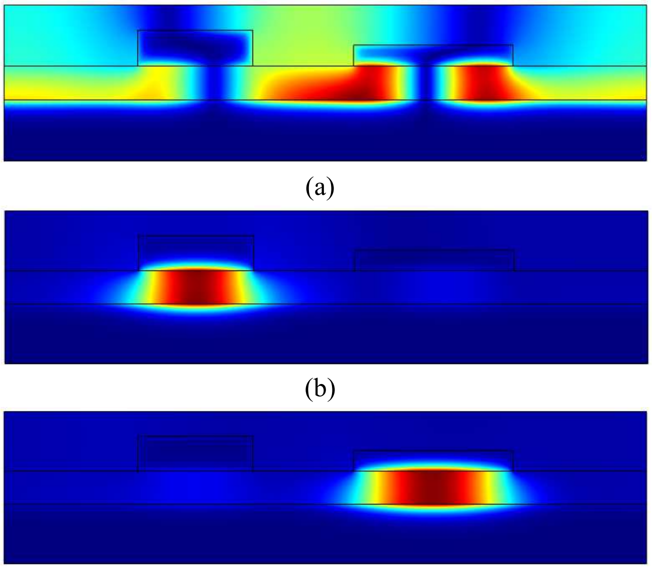


Fig. 4. Absorption spectra of the optimized absorber for TM polarization (green) and TE polarization (blue)

IV. CONCLUSIONS

In summary, we demonstrate the ability of the implemented genetic algorithm to optimize a multiband infrared absorbers composed by a multilayered metallic-dielectric with two metallic strips . The present approach can be easily adapted for the inverse design and optimization of several other photonic and plasmonic devices.



(a)

(b)

(c)

Fig. 5. Spatial field distribution at the resonant wavelengths (a) 3.7626µm (b) 4.9112µm and (c) 6.2261µm

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