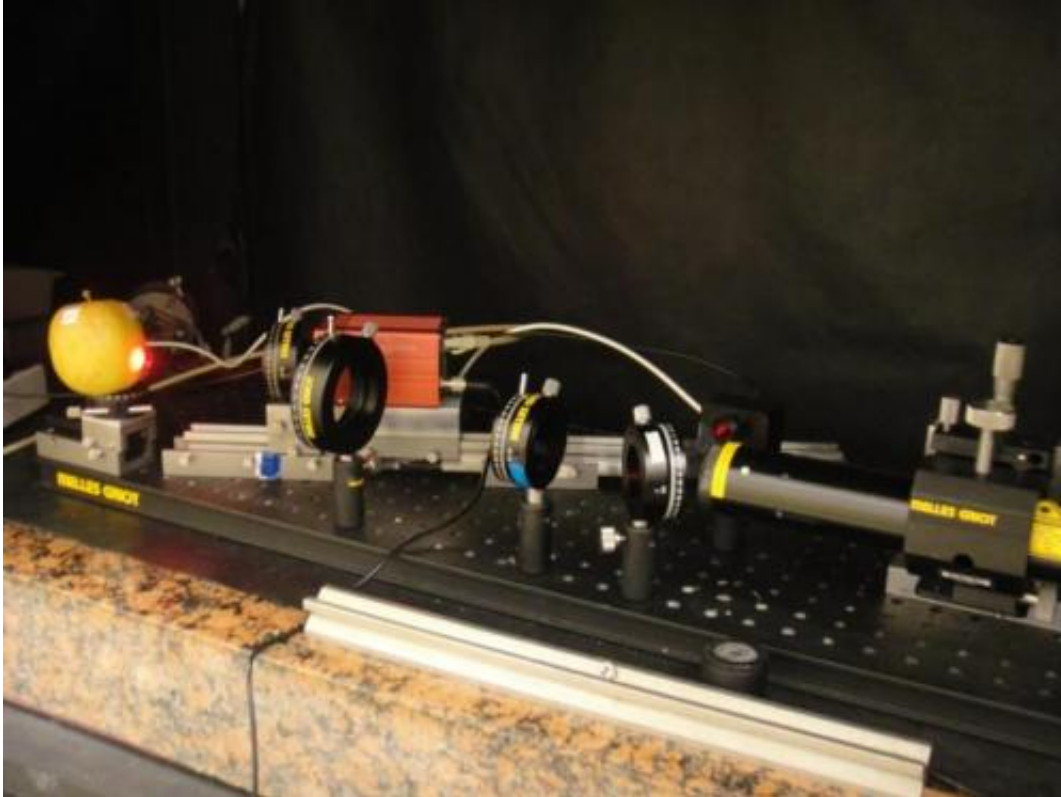


Ever tried a 'laser delicious' apple?

December 3 2014



The team's setup to measure speckle patterns involves coherent light, a laser beam, polarizers and quarter-wave plates to generate different incident polarizations, and a CMOS or CCD camera to record the fruits' speckle pattern. Credit: R.Nassif

The ability to detect when to harvest "climacteric" fruits—such as apples, bananas, pears and tomatoes—at the precise moment to ensure "peak edibility" in terms of both taste and texture may soon be within

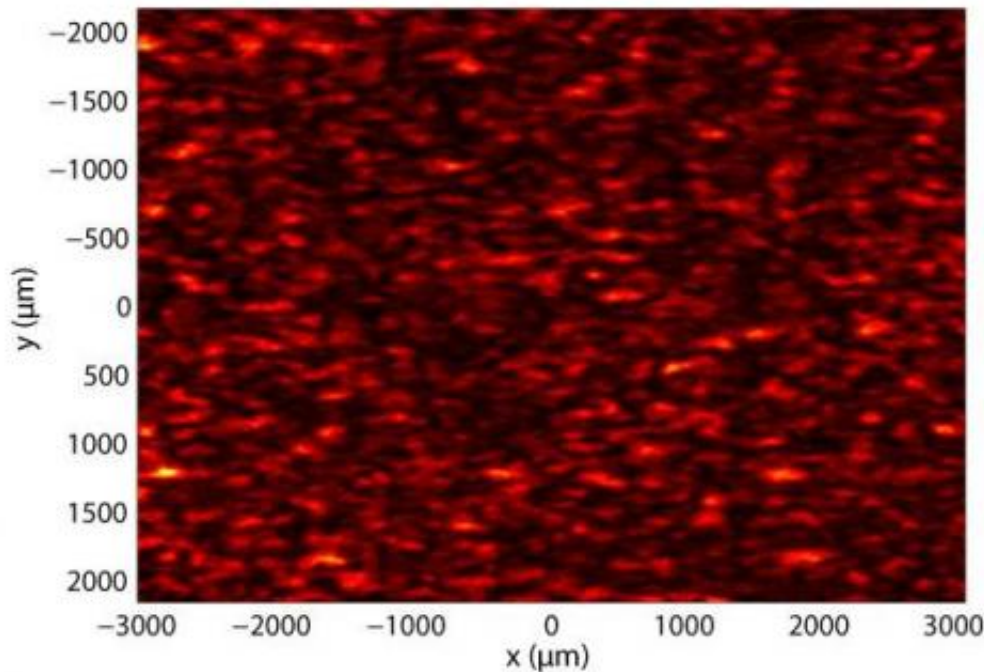
reach for farmers, thanks to the work of a team of researchers from Saint Joseph University in Lebanon and the Université de Bretagne Occidentale de Brest in France.

As the team reports in a paper published in The Optical Society's (OSA) journal *Applied Optics*, they recently demonstrated a laser biospeckle technique capable of detecting fruits' climacteric peak.

What's the significance of this climacteric peak? "Fruits are divided into two categories: climacteric or nonclimacteric fruits," explained Rana Nassif, a postdoctoral researcher affiliated with both Saint Joseph University and the Université de Bretagne Occidentale de Brest. "Climacteric fruits continue their maturation off the tree or vine, so these fruits emit ethylene and are characterized by a climacteric peak—indicating a maximum ethylene release.

"This peak signals that the fruit has reached its maturity." After this point, the fruit is more susceptible to fungal invasion or begins to degrade from cell death.

By tapping biospeckle activity, generated by illuminating a biological medium with coherent light, the researchers studied the evolution of two batches of Golden apples' speckle patterns as they underwent the ripening process in both low- and room-temperature environments.



Speckle pattern recorded when illuminating an apple. Credit: R.Nassif

To do this, the team uses a rather simple setup that involves coherent light, a laser beam, polarizers and quarter-wave plates to generate different incident polarizations, and a digital camera to record the speckle pattern. "Simplicity and low cost are the key advantages of our technique," noted Nassif.

How does it work? Laser light interacts with any medium through different processes such as scattering, absorption and reflection. Photons scattered by the medium interfere with the incident light field to create a speckle pattern. "A group of sparkling and dark grains called 'speckle grains' make up this pattern. If the medium is biological—meaning that it presents some sort of cell activity—its speckle pattern will show changes with time," she said. "And this pattern depends on the medium's scattering properties, as well as its own nature."

Once obtained, speckle patterns can be correlated with a reference standard, which is based on emitted ethylene concentrations obtained by a principal component analysis. "This approach allows us to validate biospeckle as a noninvasive alternative method to respiration rate and ethylene production, which are used today for climacteric peak detection and as a ripening index," said Nassif.

The team explored the diffusion properties and inner activity aspects of the apples via speckle grain size, recording the temporal correlation between a set of images, consecutively, in different light polarizations. "On one hand, the changes the speckle grain size underwent marked an inflection point corresponding to the climacteric peak for apples stored at room temperature. While on the other hand, the time correlation coefficient behavior demonstrated a rise in the apples' activity until the day of climacteric peak was reached, followed by a decrease that marked the beginning of the deterioration stage."

Beyond apples, Nassif and colleagues are also monitoring the ripening of "Conference" pears—performing backscattered speckle images on the fruits during the ripening phase. They supplemented these images with fluorescence and biochemical measurements.

"By doing this, we were able to show that as the glucose content increases, the circular degree of polarization decreases," Nassif said. In technical terms, she added, "This signature is expected for a medium that constituted a significant portion of small 'scatterers,' in which the Rayleigh diffusion regime outweighs the Mie regime. We also noticed a decreasing speckle grain size, which can be attributed either to increasing glucose or the decreasing of absorption."

What's next for the team? "In the near term, we're working on speckle theoretical studies based on Monte Carlo simulations—taking into account light polarization and media characteristics," said Nassif. "These

simulations can be used to differentiate and quantify the diffusion coefficient variations and its effect from those of absorption on the fruits' speckle image."

Then, they'll focus on comparing these simulations with experiments done on latex spheres—a mix of spheres of varying diameters—to vary the diffusion and absorption coefficient.

And, of course, one of the team's ultimate goals is to develop a portable tool to enable farmers to noninvasively assess their fruits' maturity in orchards or fields to detect the optimal time to harvest their crops. "This is of great interest to fruit farmers—especially since most tests used today are either destructive or based on visual criteria that are often wrong," noted Nassif.

More information: "Detection of Golden apples climacteric peak by laser biospeckle measurements," by R. Nassif et al., *Applied Optics*, Vol. 53, Issue 35, pp. 8276-8282(2014). [www.opticsinfobase.org/ao/view ... 53-35-8276&html=true](http://www.opticsinfobase.org/ao/view_full_text.do?uri=AO-53-35-8276&html=true)

Provided by Optical Society of America

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