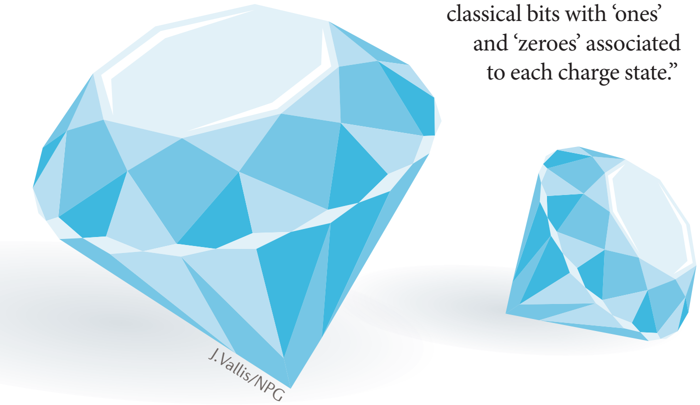
DATA STORAGE

A diamond bit is forever

“NVs can be exploited as nanoscopic classical bits with ‘ones’ and ‘zeroes’ associated to each charge state”

The amount of data that is generated and that needs to be stored is continually growing, creating demand for improved data storage methods. Carlos Meriles and co-workers, writing in *Science Advances*, present a new way to store data, demonstrating that information can be encoded with long-term stability using nitrogen-vacancy (NV) centres in diamonds.

NV centres are a type of defect in which a nitrogen atom takes the place of a carbon atom located next to an empty lattice site. These defects hold potential for various applications, ranging from nanoscale metrology to quantum information processing, for which it is necessary to connect NVs in such a way as to preserve quantum coherence. Most researchers focus on the use of photons to connect separate NVs, whereas the authors of the study are interested in an alternative route based on electrons. “Although photons are useful for long-distance communication, charge carriers are simpler to control and integrate within a chip,” explains Meriles. “With this motivation, we conducted initial tests on the carrier dynamics in diamond: it was during these experiments that we realized that NVs can be exploited as nanoscopic classical bits with ‘ones’ and ‘zeroes’ associated to each charge state.”



The idea behind this proposed method is to manipulate the charge state of the defects by illuminating them with laser light of different wavelengths. Green illumination can drive the transition of neutral NV centres to negatively charged centres and vice versa. Conversely, red light can only convert negatively charged centres into neutral ones. Because the change in the charge state of the defects is reflected in a change in their fluorescence, the charge state of the NVs can be measured using optical techniques.

To encode information, the NV-centre-containing diamond is first illuminated with green light so that all defects become negatively charged. Then a red laser beam is used to switch selected defects to the neutral state to form an image, which is revealed by scanning with a weak red laser. By varying the duration of the red light pulse, different levels of fluorescence can be attained, enabling multivalued bits that can take up to 10 distinct values (rather than the usual 2 of binary bits), boosting the information density to about as high as a hundred times that of current DVDs. If the sample is kept in the dark, the encoded information is stable; however, subsequent readings result in a gradual loss of contrast, such that the information needs to be refreshed after being read a few times. The bits can be deleted using a strong green laser that resets the sample to its initial state, after which it can be rewritten.

NV centres can withstand virtually infinite rewrites without the materials degrading. Moreover, because the illumination intensity strongly depends on the distance between the laser source and the sample, it is possible to store separate sets of bits at different depths in the diamond, enabling 3D information storage. In this particular case, information was stored at three different depths in the diamond structure.

To further boost the storage capacity it would be necessary to overcome the optical diffraction limit (light cannot be focused to a spot smaller than half of its wavelength). Super-resolution microscopy techniques allow objects smaller than the diffraction limit to be imaged, but because such methods are based on the same principle used in this study to encode information in the NV centres, the information in the sample would be altered. Meriles and co-workers are hoping to overcome this obstacle by temporarily storing the information associated with the charge of each NV centre in its spin orientation, which is not influenced by light, and re-establishing the original charge after the super-resolution writing or reading process is completed. “Extensions of this work could reduce the bit size by about two orders of magnitude, which would allow storage capacities greatly exceeding those possible using existing technologies,” concludes Meriles.

Giulia Pacchioni

ORIGINAL ARTICLE Dhomkar S. *et al.* Long-term data storage in diamond. *Sci. Adv.* **2**, e1600911 (2016)

FURTHER READING Doherty, M. W. *et al.* Towards a room-temperature spin quantum bus in diamond via optical spin injection, transport and detection. Preprint at https://arxiv.org/abs/1511.08559 (2015) | Jayakumar H. *et al.* Optical patterning of trapped charge in nitrogen-doped diamond. *Nat. Commun.* **7**, 12660 (2016) | Gu, M. *et al.* Nanomaterials for optical data storage. *Nat. Rev. Mater.* **1**, 16070 (2016)