Raman spectroscopy:
A 90-year story of the intersection of science and technology

Science on Tap: September 7, 2017

Andrew Shreve, UNM

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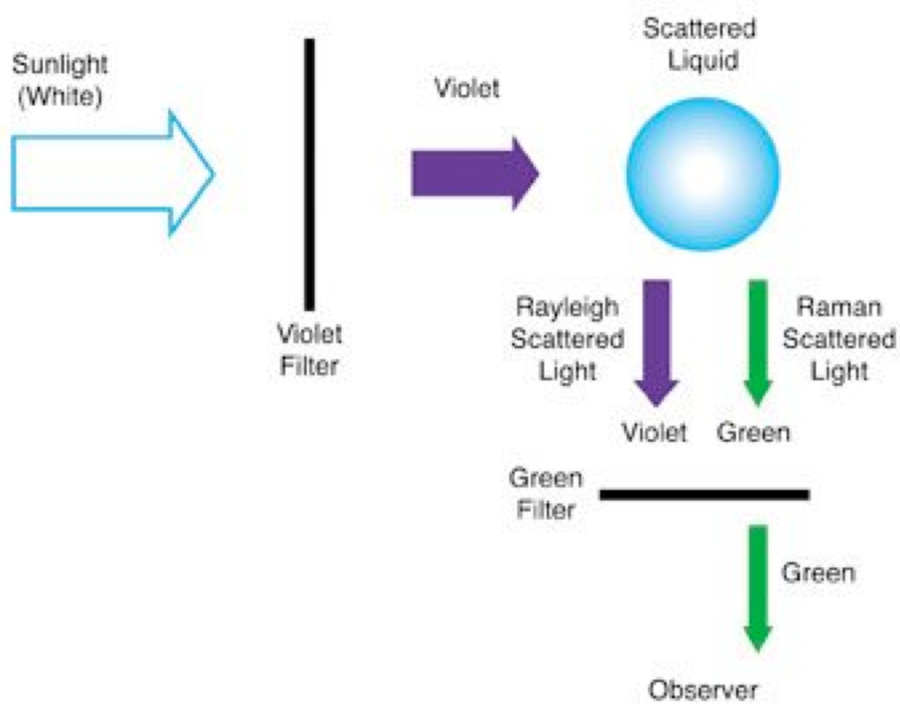
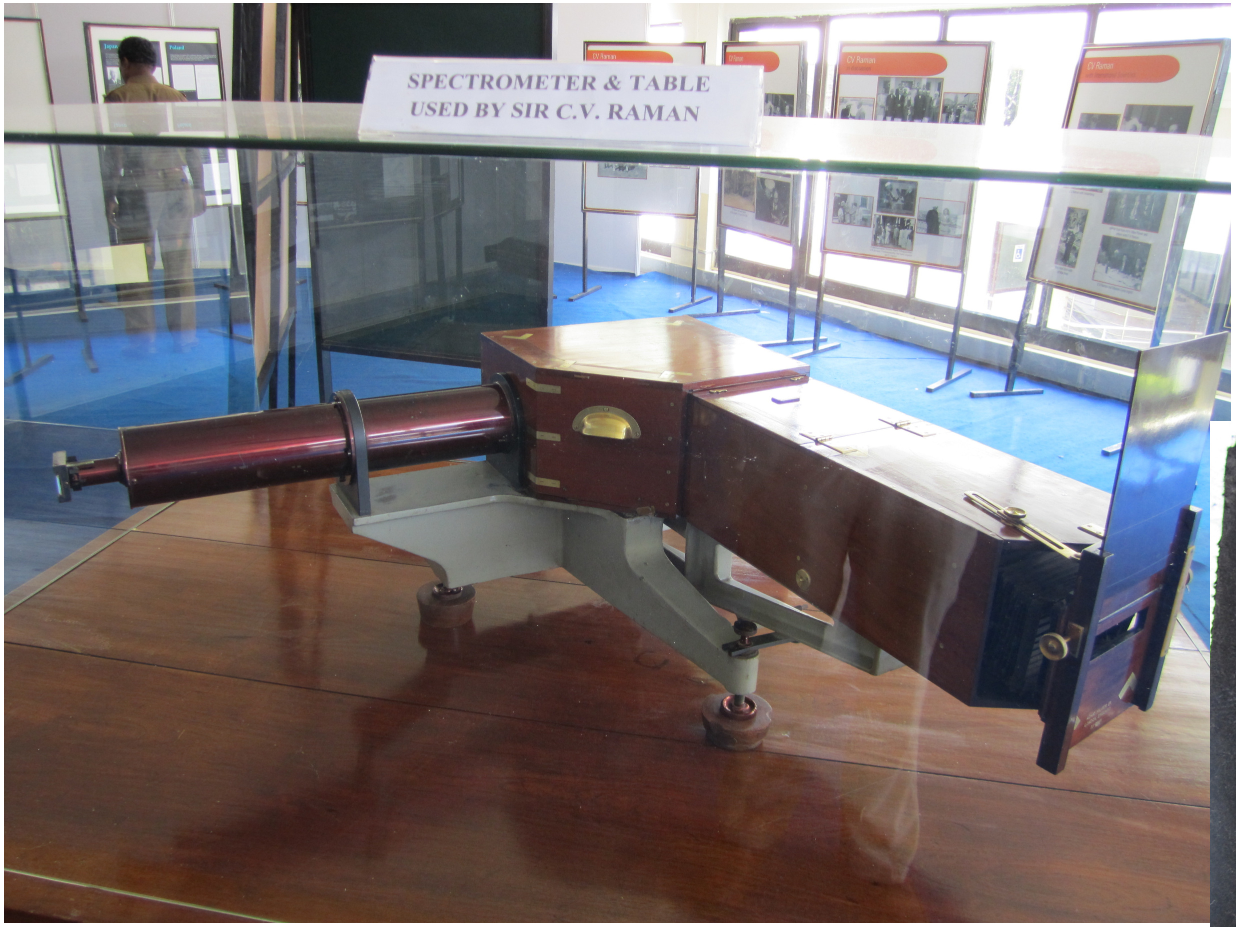
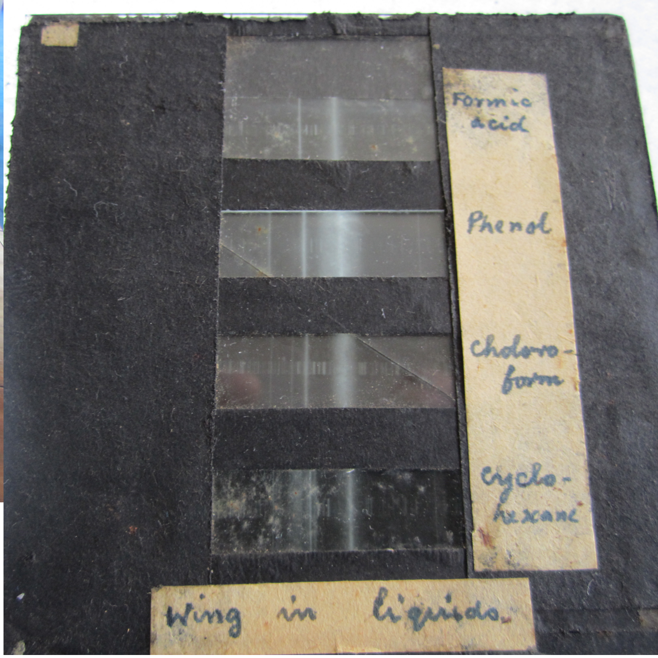


Image from:
https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/ramaneffect.html

Raman Effect:

C.V. Raman, K.S. Krishnan, "A new type of secondary radiation," *Nature* **121** (1928) 501-502





Stimulated Optical Radiation in Ruby

Schawlow and Townes[1] have proposed a technique for the generation of very monochromatic radiation in the infra-red optical region of the spectrum using an alkali vapour as the active medium. Javan[2] and Sanders[3] have discussed proposals involving electron-excited gaseous systems. In this laboratory an optical pumping technique has been successfully applied to a fluorescent solid resulting in the attainment of negative temperatures and stimulated optical emission at a wave-length of 6943 Å.; the active material used was ruby (chromium in corundum).

A simplified energy-level diagram for triply ionized chromium in this crystal is shown in Fig. 1. When this material is irradiated with energy at a wave-length of about 5500 Å., chromium ions are excited to the $^4F_2$ state and then quickly lose some of their excitation energy through non-radiative transitions to the ^2E state[4]. This state then slowly decays by spontaneously emitting a sharp doublet the components of which at 300° K. are at 6943 Å. and 6929 Å. (Fig. 2*a*). Under very intense excitation the population of this metastable state (^2E) can become greater than that of the ground-state; this is the condition for negative temperatures and consequently amplification via stimulated emission.

To demonstrate the above effect a ruby crystal of 1-cm. dimensions coated on two parallel faces with silver was irradiated by a high-power flash lamp;

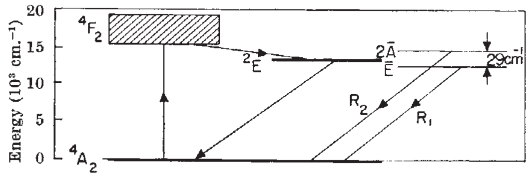


Fig. 1. Energy-level diagram of Cr^{3+} in corundum, showing pertinent processes

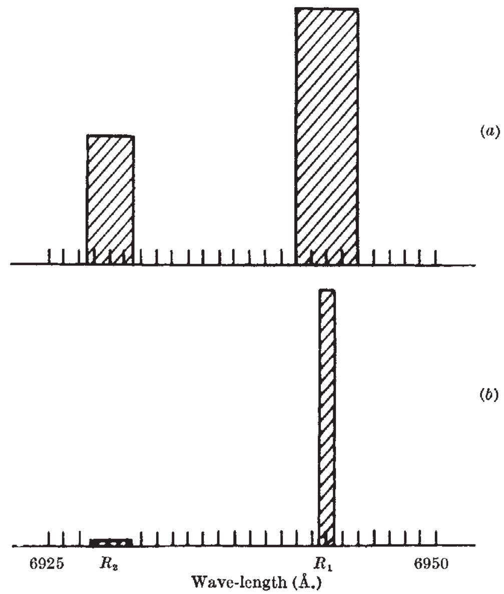


Fig. 2. Emission spectrum of ruby: *a*, low-power excitation; *b*, high-power excitation

the emission spectrum obtained under these conditions is shown in Fig. 2*b*. These results can be explained on the basis that negative temperatures were produced and regenerative amplification ensued. I expect, in principle, a considerably greater ($\sim 10^8$) reduction in line width when mode selection techniques are used[1].

I gratefully acknowledge helpful discussions with G. Birnbaum, R. W. Hellwarth, L. C. Levitt, and R. A. Satten and am indebted to I. J. D'Haenens and C. K. Asawa for technical assistance in obtaining the measurements.

T. H. Maiman

Hughes Research Laboratories,
A Division of Hughes Aircraft Co.,
Malibu, California.

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T.H. Maiman, *Nature* 187 (1960) 493-494.

United States Patent [19]
Boyle et al.

[11] **3,796,927**
[45] **Mar. 12, 1974**

[54] **THREE DIMENSIONAL CHARGE COUPLED DEVICES**

[75] Inventors: **Willard Sterling Boyle,** Summit; **George Elwood Smith,** Murray Hill, both of N.J.

[73] Assignee: **Bell Telephone Laboratories, Incorporated,** Murray Hill, Berkeley Heights, N.J.

[22] Filed: **Dec. 16, 1970**

[21] Appl. No.: **98,619**

[52] **U.S. Cl.** .... **317/235 R,** 317/235 G
[51] **Int. Cl.** **H01l 11/14**
[58] **Field of Search**......... 317/235; 307/238, 220 C, 307/1, 22 GC, 307; 340/173 CA

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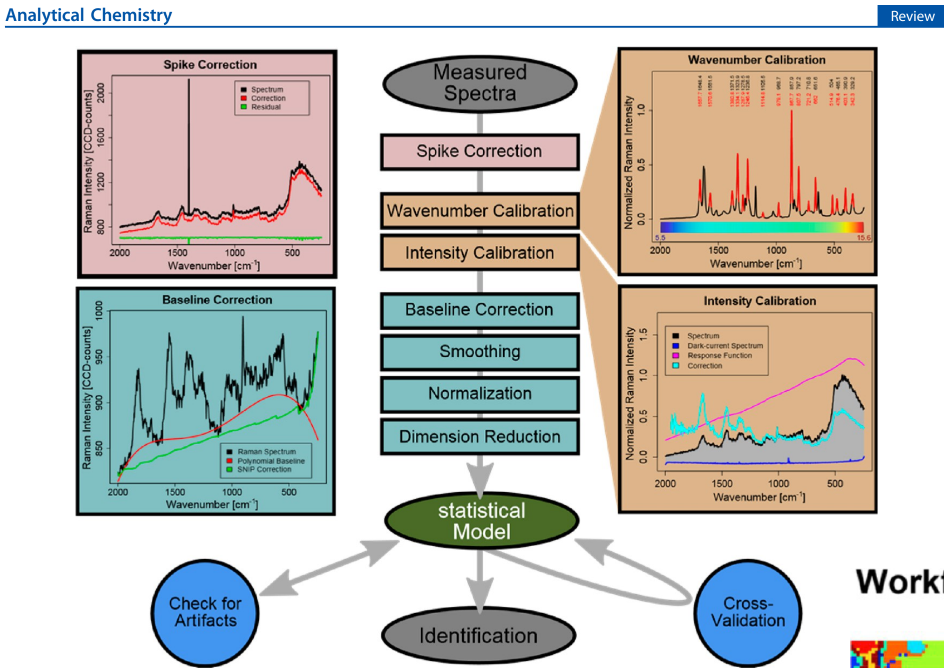
Electronics, "Overlap Key to G.E.'s Charge–Coupled Device" pages 33, 34, Nov. 9, 1970.

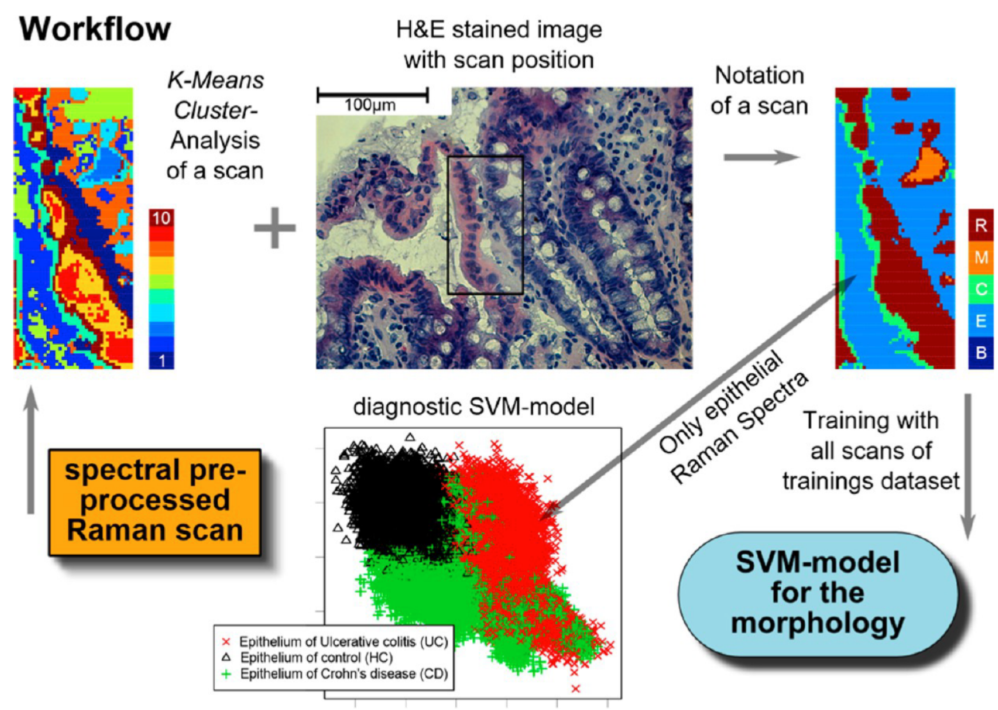
Primary Examiner—Jerry D. Craig
Attorney, Agent, or Firm—P. V. D. Wilde

[57] **ABSTRACT**

The specification describes a new class of semiconductor devices in which the charge is controllably translated in three dimensions. Translation control circuits can be disposed on both sides of the usual semiconductor wafer giving a new dimension in the design of logic and memory devices. In the exemplary specific embodiment the concept is described in connection with a shift register. Extension to logic circuits, e.g., to perform crossover and fan-in functions, is straightforward.

10 Claims, 10 Drawing Figures





Images from: T.W. Bocklitz,..., J. Popp, *Analytical Chem.* 88 (2016) 133-151.

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

Raman spectroscopy analysis of pigments on 16–17th c. Persian manuscripts

Vânia S.F. Muralha[a,*], Lucia Burgio[a,b], Robin J.H. Clark[a]

[a] Christopher Ingold Laboratories, University College London, 20 Gordon Street, London WC1H 0AJ, UK
[b] Victoria and Albert Museum, Science Section, Conservation Department, London SW7 2RL, UK

ARTICLE INFO

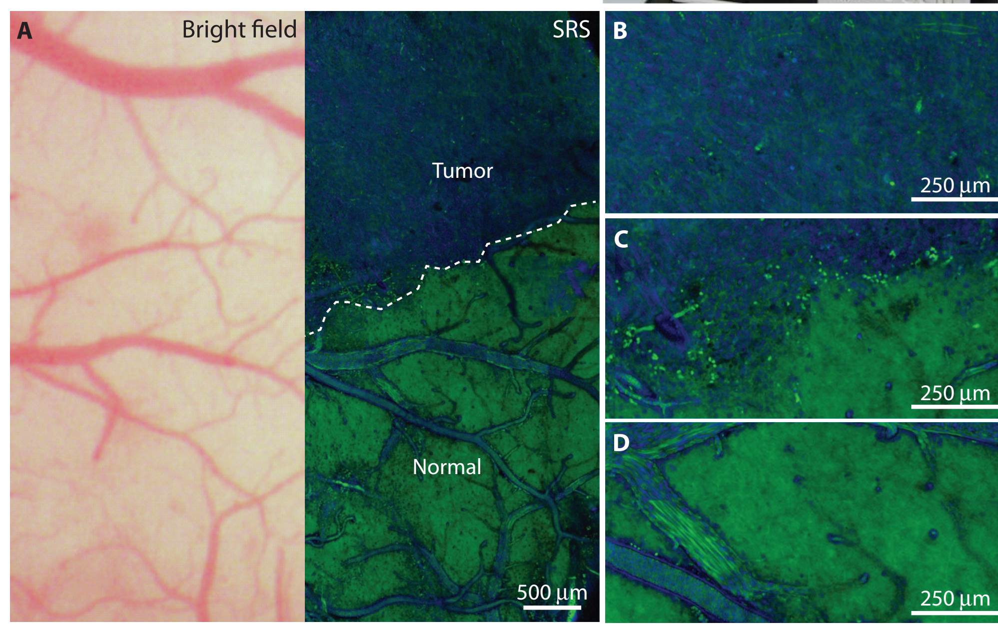
Article history:
Received 1 November 2011
Received in revised form 31 January 2012
Accepted 6 February 2012

Keywords:
Raman microscopy
Pigments
Persian manuscripts
Pigment mixtures

ABSTRACT

The palette of four Persian manuscripts of the 16th and 17th centuries were established by Raman microscopy to include lazurite, red lead, vermilion, orpiment, a carbon-based black, lead white, malachite, haematite, indigo, carmine and pararealgar. The first five pigments were identified on all four manuscripts, as previously found for other Islamic manuscripts of this period. The findings were compared with information available in treatises on Persian painting techniques. Red lead, although identified on all of the manuscripts analysed in this study as the main red pigment, is seldom mentioned in the literature. Two unusual pigments were also identified: the intermediate phase between realgar and pararealgar in the manuscript *Timur namah*, and carmine in the manuscript *Shah namah*. Although the established palette comprises few pigments, it was found that the illuminations were enhanced by the use of pigment mixtures, the components of which could be identified by Raman microscopy.

Figs. 1–3. **(1)** Double-page frontispiece from the manuscript *Timur Namah* (MSL/1876/699). Locations of the Raman analyses are indicated numerically. **(2)** *Unwan* from the manuscript *Timur Namah* (MSL/1876/699). Locations of the Raman analyses are indicated numerically. **(3)** *Unwan* from the manuscript *Layla we Majnum* (MSL/1885/359). Locations of the Raman analyses are indicated numerically.



Images from:
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M. Ji, ..., X.S. Xie, *Science Translational Medicine* **5** (2013) 201ra119


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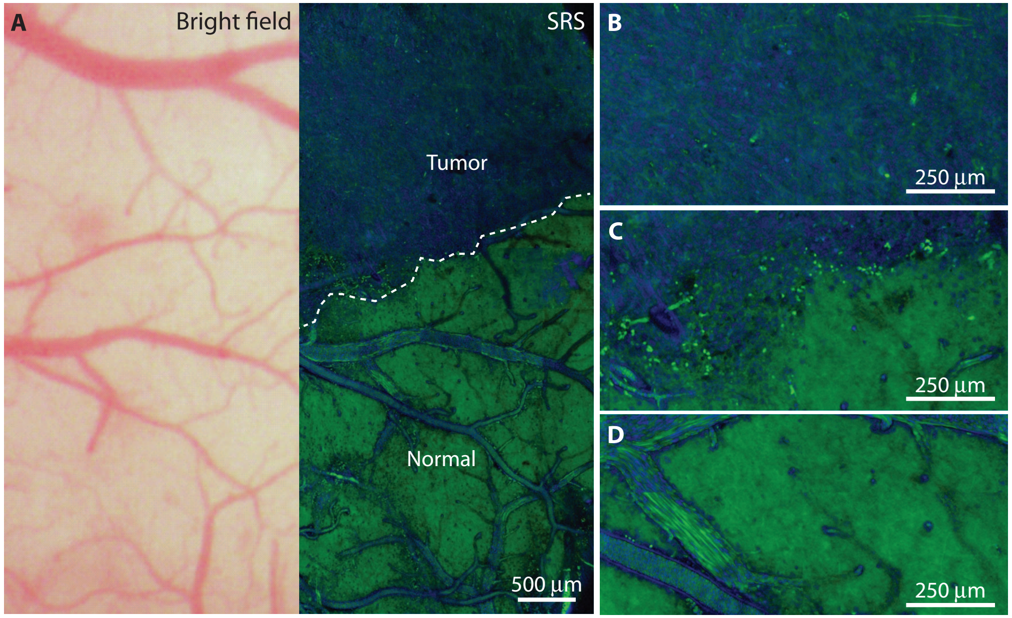
A
Bright field
SRS
Tumor
Normal
500 µm
B
250 µm
C
250 µm
D
250 µm