One Hundred Years of Photo Physics
One Hundred Years of Photo Physics
“Professor Mitchell, people still do silver halide photography!”
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or:

“Professor Mitchell, people *still* do silver halide photography!”

Memorial Colloquium in Honour of J.W. “Jack” Mitchell

Keith Williams, UVa September 2007
One Hundred Years of Photo Physics

I. Introduction

II. Timeline from B.C. to 2007

III. The Contributions of J.W. Mitchell

IV. Silver Halide in the Modern Era

V. The Digital Future
One Hundred Years of Photo Physics

I. Introduction

II. Timeline from B.C. to 2007
   (with particular emphasis on 1900-present)

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V. The Digital Future
Photography Timeline

1700  1750  1800  1850  1900  1920  1940  1960  1980  2000

Pinhole cameras

- Mo Ti, China (500 B.C.) : pinhole camera
- Aristotle (330 B.C.) : pinhole observation of eclipse

A modern pinhole image from Charlottesville (5x7")
Photography Timeline

Photosynthetic process
…without glass lenses or photoemulsions??

Binh Danh
Left: The Leaf Effect: Study for Metempsychosis #7 (2006)
James Pennell: Vermeer may have used a camera obscura (1891)
David Hockney: concave mirror could have been used...

Camera obscura used by Vermeer?

How the Camera Obscura Works

1. In one approach, the image of a subject passes through a small opening in the wall of a darkened room onto a mirror.
2. The image is reflected off the mirror onto a canvas or piece of paper hung on the opposite wall. The image is now traced. Then the canvas can be turned right side up and the work finished from real life.
Philip Steadman’s analysis

Camera obscura used by Vermeer?
Photography Timeline

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Philip Steadman’s analysis

Camera obscura used by Vermeer?

Top: 1/6th scale model, plus camera…
Right: photograph reproduces the rays in Vermeer’s composition
Schulze and Scheele’s Photosensitive concoctions (chalk + nitric acid + silver)

Scheele’s reactions (1777):

\[
\begin{align*}
\text{Ag}^+ + \text{Cl}^- + \text{light} & \rightarrow \text{Ag}^+ + \text{Cl} + \text{1e}^- \quad \text{(oxidation)} \\
\text{Ag}^+ + \text{1e}^- & \rightarrow \text{Ag (metal)} \quad \text{(reduction)}
\end{align*}
\]
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\{ oxidation \}
\{ reduction \}

Remember this redox cycle !!!
Nicéphore Niépce’s photopaper and the “1st permanent image”

T. Wedgwood’s images were impermanent...
Henry Fox Talbot’s calotype process

• Developed in 1841
• Paper coated with silver iodide
• Light exposure produces metal and liberates halide, and metal is then oxidized (turns black)
• KBr stabilizes the silver oxide
• Salt prints made from calotype negative after washing
Louis Daguerre’s “daguerreotypes”

- Image cast directly on polished plate coated with silver and silver halide from halide vapour (expensive and laborious)

Source: Scientific American 56(4), 47-52 (1887)
Daguerreotypes

- Camera obscura
- Silver plate
- Iodine and Bromide Boxes
- Improved Mercury Cabinet with sliding legs
- Plate holders with clamps
- Box for Plates
- Levelling stand
- Flat peculiar dish for washing
- Hand-buff

D-type kit, 1843*

*http://www.photohistory-sussex.co.uk/dagprocess.htm
Daguerreotypes

- Image cast directly on polished plate coated with silver and silver halide from halide vapour (expensive and laborious)

- Image is a negative but appears positive if light orientation is correct

- Direct-print process: no negative is generated and so images cannot be duplicated

*http://www.photohistory-sussex.co.uk/dagprocess.htm

Posing stand *
Daguerreotypes

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Abraham Lincoln, ~1840 - “The Kaplan daguerreotype”
**Daguerreotypes**

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Edgar Allan Poe, ~1848
Herschel and Atkin’s cyanotype process

- Uses two primary aqueous chemicals, ammonium Fe(III) citrate and potassium ferricyanide, to form a photosensitive coat on paper
- UV exposure reduces Fe(III) to Fe(II), which then reacts with ferricyanide to form water-insoluble dye “Prussian blue” which stays on paper
- Source of the term “blueprints” used in architecture & engineering
- Similar process: gum bichromate

Floral cyanotype; courtesy of Diwan Bhathal
Photography Timeline

James Clerk Maxwell’s colour separation photography

Young Master James with his colour wheel
U.S. Civil War – first extensive wartime photojournalism (Mathew Brady et al)
Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Eadweard Muybridge-
horses in motion

(Electronically triggered)
George Eastman’s roll film

- Roll film patented in 1884
- Roll film camera patented in 1888; “Kodak” also created that year
- Sold 100,000 cameras in only ten years
- $1 Brownie introduced in 1900
- Suicide in 1932
- Donated $100M in his life, anonymously, to Rochester University and to MIT

2007: 107th birthday of the brownie

See http://www.brownie-camera.com
Photography Timeline

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Oskar Barnack’s Rangefinder
birth of Leitz Camera
(a.k.a. Leica)

Barnack
Photography Timeline

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Oskar Barnack’s Rangefinder birth of Leitz Camera (a.k.a. Leica)

Leica M8 (2006), the first truly pro-grade digital manual focus RF
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Harold ("Doc") Edgerton’s strobe photography at MIT (late ’20s on)
Edwin Land’s “polaroid”

- Patented in 1929
- Trivia: Land designed the optics for the U2 spy plane
- Trivia: Land was one of the richest scientists... ever.
- 20x24” polaroid cameras are still in operation

Ansel Adams, *Arches, North Court, Mission San Xavier del Bac* (1968) captured on Polaroid Type 55 “pos/neg” film
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20x24” Celebrity Polaroid
Timothy Greenfield
Formation of “Group f/64” by Weston, Adams, Cunningham, and Van Dyke

Edward Weston

Shell
Edward Weston
Formation of “Group f/64” by Weston, Adams, Cunningham, and Van Dyke
Photography Timeline

Henri Cartier-Bresson begins work with Leica

Henri Cartier-Bresson
Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Theory of Latent Image Formation - Gurney & Mott (1938)

*http://www.cheresources.com/photochem.shtml
Photography Timeline

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“Beauty heretofore impossible”

Pan films
Kodak ~1930
**UV and IR photography**

Robert Williams Wood

- Sensitizers had been previously discovered
- Developed “Wood’s glass” to block visible light
- Proposed use of UV for secret communication
- First to do UV fluorescence
- Glowing of trees in IR photos is called the Wood effect
- Less atmospheric scatter in IR; \( 1/\lambda^4 \) (Rayleigh)
Photography Timeline

Modern IR photography

Central Park (2006)
Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Modern IR photography

Albemarle (2007)
Photography Timeline

Modern IR photography

Mares and Foals (2006)
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Robert Capa
War-time photography

Loyalist Militiaman at the Moment of Death, Cerro Muriano, September 5, 1936.

D-day landings, 1944

"The desire of any war photographer is to be put out of business." - Capa
Adobe Photoshop (1988)

the digital darkroom emerges…
Adobe Photoshop (1988)

the digital darkroom emerges…

… and hybrid photography is born.
First “pro” DSLR-
Introduced by Kodak, 1991

- Based on Nikon F3 body
- 1.3 megapixel
- 3.5” hard drive
- External module to visualize images
Photography Timeline

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Canon and Nikon full-frame DSLRs

Epson RD1 and Leica M8 DRFs
Photography Timeline

2007: Lots of people still use film!

www.apug.org

One Hundred Years of Photo Physics

I. Introduction

II. Timeline from B.C. to 2007

III. [Some of the] Contributions of J.W. Mitchell

- photographic sensitivity
- hole migration
- role of dislocations
- control of fogging

IV. Silver Halide in the Modern Era

V. The Digital Future

Keith Williams, UVa September 2007
Unexposed Silver halide grain and adsorbed sensitivity center

Exposure

Reduced silver halide molecule

Latent image formation

Developable latent image site

Development

Fixed silver image grain

Fixing

Developed silver image
Ag⁺ + Cl⁻ + light → Ag⁺ + Cl⁻ + 1e⁻  \textit{oxidation}

Ag⁺ + 1e⁻ → Ag \textit{(metal)}  \textit{reduction}
Ag⁺ + Cl⁻ + light -> Ag⁺ + Cl + 1e⁻  \textit{oxidation}

Ag⁺ + 1e⁻ -> Ag (metal)  \textit{reduction}

Lattice!
The Silver Halide Process: where and what is the **latent image**, actually?

Gurney and Mott (1938):

Photoelectrons migrate to traps (sensitivity centers), where they form a silver speck- this is the latent image.

Berg (1948):

There are external (surface) and internal latent images.

Mitchell (1955-):

A hole is also generated upon photoexcitation, recombination is avoided because holes are trapped by surface halide ions or adsorbed sensitizer molecules.

Silver sulfide sensitivity centers are formed preferentially where dislocations meet the crystal surface.

Internal latent image is formed by separation of silver atoms along dislocation lines.

Condition for a stable latent image: 4 silver atoms per crystal.
Minimum requirements for a stable (developable) latent image:


Photographic Sensitivity

traps for conduction electrons at room temperature but do trap positive holes and may therefore suffer regression. The latent sub-image specks are transformed into stable latent image specks of minimum size by combination with an interstitial silver ion and conduction electron. At this stage, a critical change in the mechanism takes place: the group of three silver atoms, which has been formed from interstitial silver ions and electrons by the processes which have been outlined, can adsorb a silver ion from the surface of the silver halide crystal and thus become positively charged in thermal equilibrium at room temperature, the compensating negative charge being provided by a vacant silver ion lattice site in the neighbourhood. These and all larger groups of silver atoms which are positively charged repel positive holes, and are therefore protected from regression. They trap conduction electrons and the positive charge is then immediately restored to the uncharged speck by the adsorption of a further silver ion from the surface and the formation of a vacant silver ion lattice site. The potential differences arising from the trapping of the positive holes and electrons at separated sites are eliminated by the motion of silver ions and, through a succession of such processes, the silver specks increase in size until they become visible particles of photolytic silver.

Mitchell (1957)
Energy levels involved in the formation of the latent image in crystals of silver bromide

1. Energy levels within the crystals: AB, the conduction band; BC, the forbidden band; CD, the full band.

2. Localized energy levels at the surfaces of the crystals: BB_s, range of unoccupied levels associated with surface silver ions; C_sC, range of occupied levels associated with surface halide ions.

3. Localized levels associated with molecules of silver sulphide adsorbed at sites adjacent to surface silver ions: ab, acceptor levels which provide very shallow traps for conduction electrons; E'E, range of highest occupied levels which furnish traps for positive holes.
The Silver Halide Process: how not to fog the image

Hamilton (1978)
The Silver Halide Process: grain

cubic  octahedral  tabular

Ilford delta films: epitaxial (core shell) grains

Hamilton (1978)
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IV. Silver Halide in the Modern Era
   - equipment diversity
   - resolution
   - camera movements
   - output options

V. The Digital Future

Keith Williams, UVa September 2007
Camera Movements- the **Scheimpflug** principle ~1904

Toyo view camera

Canon t&s lens

Lensbaby
But… poor reproducibility, low resolution, few focal length options, severe falloff etc.
Camera Movements – a Renaissance

~1950s era press camera

David Burnett, Nat. Geo.
Gigapixel Project

- ULF 9x18 inch plate camera (same as used in U2 spy plane)
- Kodak aerial roll film, resolution: 4000 pixels per inch

Graham Flint*

Gigapixel Project
Gigapixel Project
Gigapixel Project
Gigapixel Project
Film vs. digital:
Image detail comparisons…

39 mp digital back       drum-scanned velvia 4x5”

Digital 39mp system: $30k!!!

4x5 system: $500

39 mp digital back  
drum-scanned velvia 4x5”

Who do we care about megapixels?!

To double the resolution, you must quadruple the megapixel count!
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V. The Digital Future
   - Full(er) frame DSLRs at lower cost
   - Digital backs at lower cost
   - Foveon architecture as opposed to Bayer
   - The camera of the future?

Keith Williams, UVa September 2007
"I am sure the next step will be the electronic image, and I hope I shall live to see it. I trust that the creative eye will continue to function, whatever technological innovations may develop."

- Ansel Adams