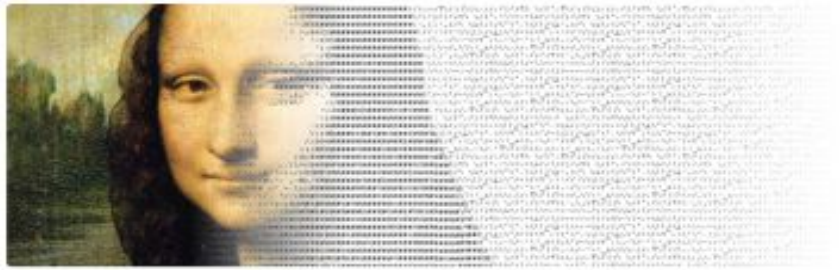

imaging & media lab

Dust BW: Detection of dust and scratches on photographic silver halide (black/white) material by polarized dark field illumination

JTS2010 Symposium, Oslo

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The problem

Photographic materials are rather unstable compared to other cultural objects. The degradation is much faster than those of paintings, sculptures or architecture. There are several factors that limit the permanence of photographic material

- In color material the dyes bleach with time
- in b/w material the finely spread silver particles are oxidizing and hence discoloring
- the film base itself (cellulose acetate / nitrate) degrades and shrinks
- mechanical wear and abrasion produce dust and scratches.

The problem

The goal of this project is to investigate a solution for one particular problem, the **removal of dust** and if necessary scratches on **any kind** of scanned transparent photographic material (film, still photographs, b/w and colour) by detection of dust through a new optical scanning system consisting of polarized dark field illumination

Digital movie restoration and photo retouching: Removal of dust and scratches

Dust and scratches are a trouble as well in classical as in digital photography and movie film. Different techniques are used to remove them, each has its advantage but also its limitations. The main approaches for dust and scratch removal are

- Chemical and mechanical removal
- Digital image processing
- Computational photography

Chemical and mechanical dust and scratch removal

Dust can be removed mechanically: pressurized air combined with electrostatic discharging and/or applying the film on a dust removal roller with a sticky surface. This is a low-budget method and the efficiency is not very high, especially when dirt is sticking in the emulsion or film base.

The chemical cleaning method comprises immersing the film into a cleaning solvent (a halogenated hydrocarbon, i.e. 3-bromo-1,1,1-trifluoropropane, perchlorethylene. 1,1,1-trichloroethane, n-propylbromide).

Chemical and mechanical dust and scratch removal

Immersing the film into a solvent is the most efficient method to eliminate scratches in the film base. In a wet gate, liquid having a refractive index close to that of the film base is applied to the original. The liquid fills the scratches and reduces the light scatter.

Mechanical and chemical cleaning is done since years in photography and movie film printing. The main disadvantage of chemical methods is the fact that the chemicals used are environmentally and toxicologically hazardous, which makes movie restoration quite expensive.

Digital image processing - movie film restoration

Restoration of movie-films was and still is an inevitable step for preservation. Traditionally this was done using photochemical methods. Since several years, with the strong spreading of digital imaging technologies, digital methods for restoration are replacing analog techniques. Digital technologies are often able to remove dirt and scratches, repair tears and restore color that cannot be handled by the traditional hands-on process.
In recent years several research-projects about digital movie restoration have been done, e.g.

AURORA (AUtomated Restoration of ORiginal film and video Archives) and BRAVA, PRESTO (Preservation Technology for European Archives) and the actual project PRESTOSPACE
Software development for movie restoration: FRAME, DIAMANT, RETOUCHE, LIMELIGHT, PFClean, Correct V8, etc.

Digital image processing - movie film restoration
Research at the IML

- Digital reconstruction of faded color photographs and movie film (≈ 1987)
- Digital restoration of movie films: dust and scratches (≈ 1994)
- New scanning approach to motion picture digitizing (≈ 1996)

What happens to fading color photographs?

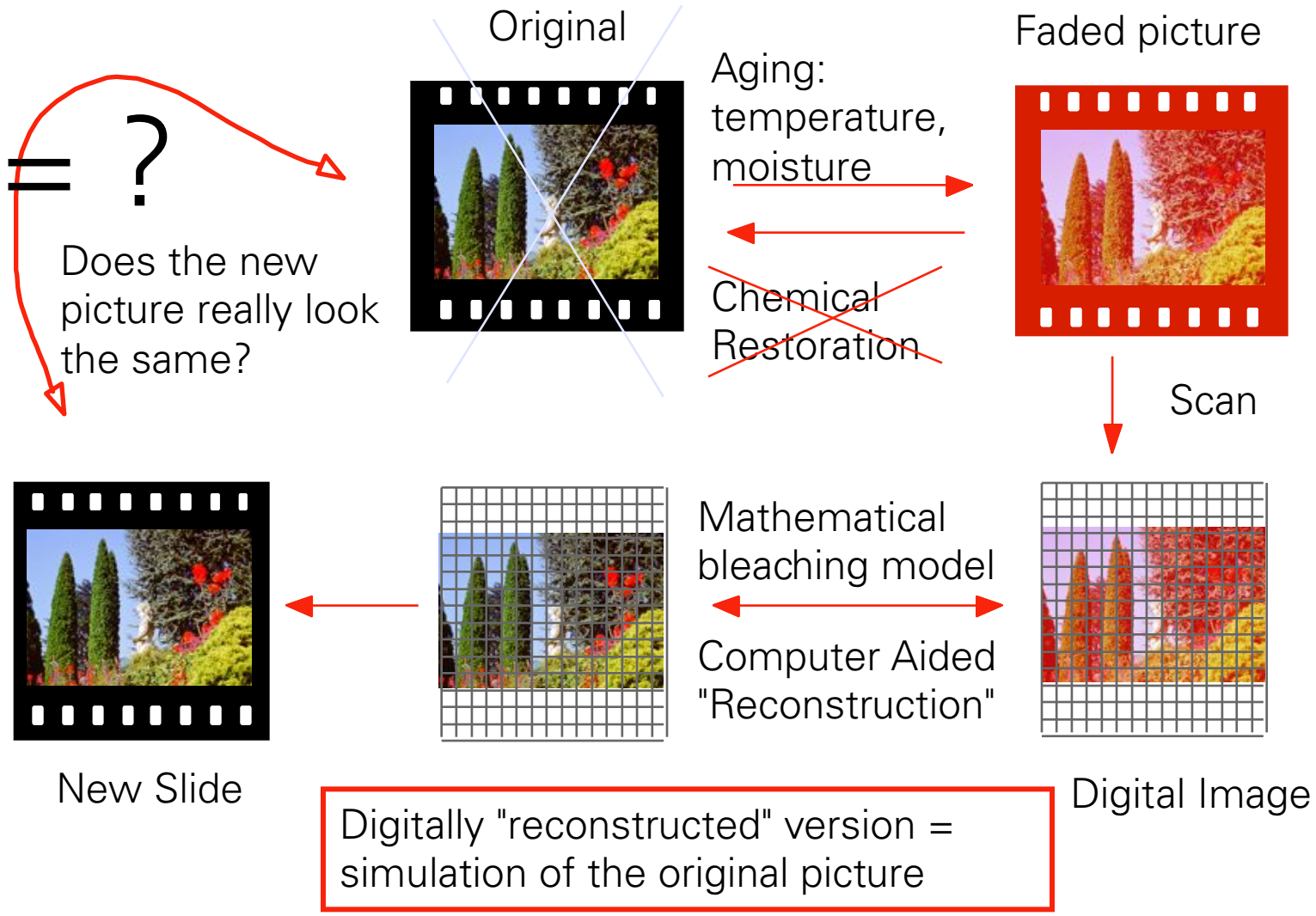
Color photograph
3 strata with color dyes

YELLOW
MAGENTA
CYAN

As a result of fading the photograph turns reddish

Unfortunately the photographic dyes are not sufficiently stable and are destroyed by light and air moisture. In the above example the Cyan dye is being destroyed: The Cyan-part image looses contrast.

The principle of digital reconstruction



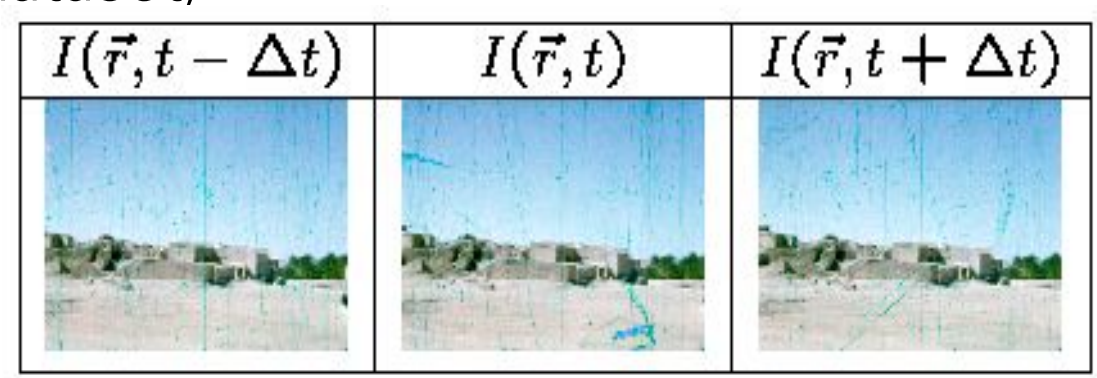
- R Gschwind and F. Frey, Electronic Imaging, a Tool for the Reconstruction of Faded Color Photographs, J. of Imaging Science and Technology, 38(6), p. 520, 1994
- F. Frey and R. Gschwind, Mathematical bleaching models for photographic three-color materials, J. of Imaging Science and technology, 38(6), p. 513, 1994

an example: a film still from *Blaubart* ,1951

Another problem: dust and scratches

Elimination of Scratches, Dust, etc.

- Requirements
  - algorithms without human interaction
  - independence of scene contents (stability)
  - use spatial and temporal information (movie sequence = 3-dim. dataset)
  - be on the safe side



- Steps
  - eliminate vertical scratches
  - detect and compensate camera pan
  - detect dust, fingerprints and other bad spots

Result of Scratch and Dust Removal

- L. Rosenthaler, R. Gschwind; Restoration of old Movie Films by Digital Image Processing; Proceedings of the European Workshop on Image Analysis and Coding for TV, HDTV and Multimedia Applications (HAMLET Race 2110 Workshop), February 27-28th 1996, Rennes
- R. Gschwind, L. Rosenthaler, A. Wittmann, W. Graff and A. Gunzinger: "Restoration of old movie films by digital image processing", in Care of Photographic, Moving Image & Sound Collections Conference 1998,York (GB), July 1998, Susie Clark editor, p150-155, ISBN 0 9533229 1 2

Computational photography - removal of dust with infrared scanning

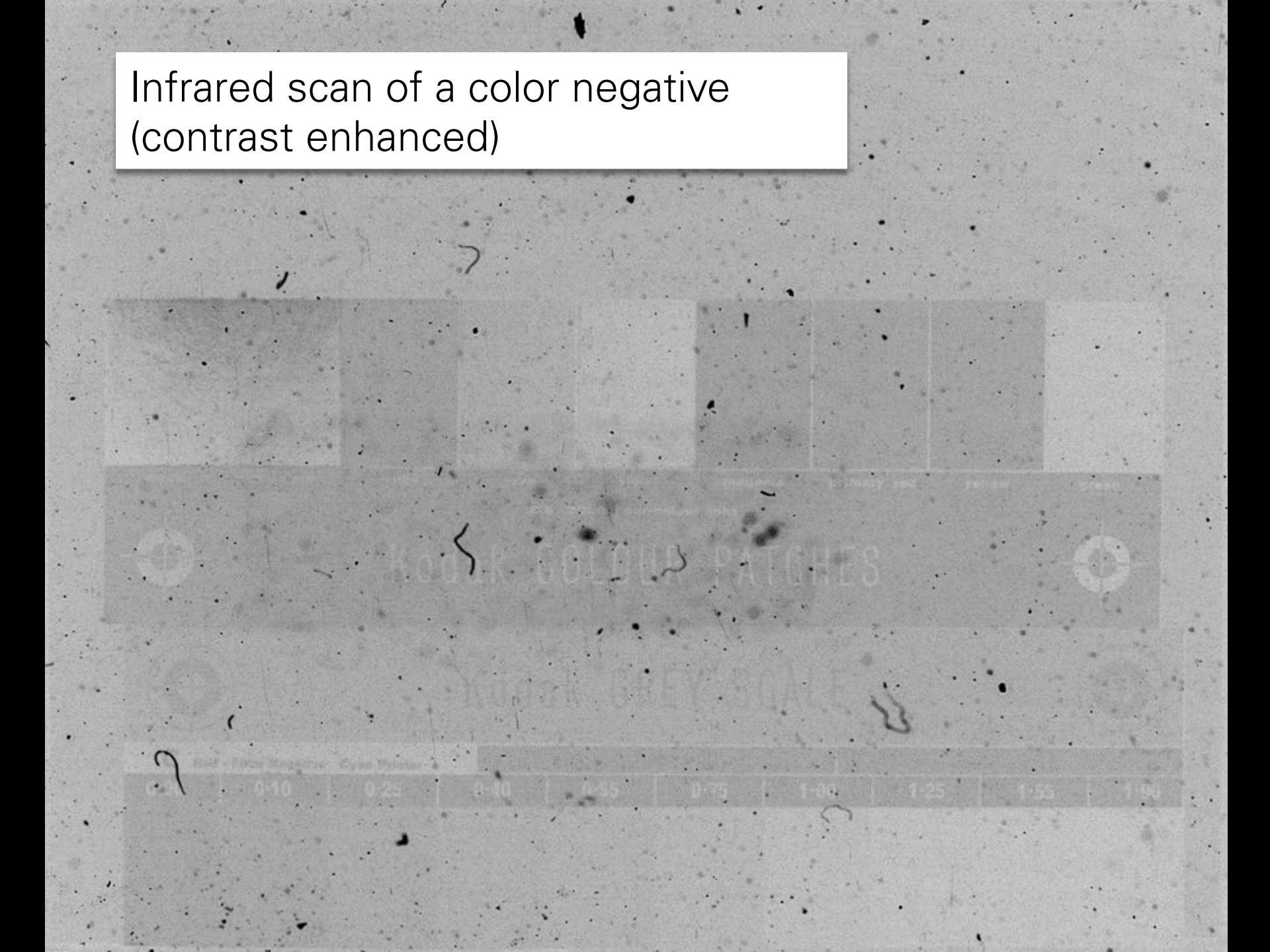
In the case of color photographs, „infrared cleaning“ can be used. Infrared cleaning works by collecting an additional infrared channel from the scan at the same time as the visible color channels (red, green, and blue).

Photographic color film is mostly transparent to infrared radiation (no matter what the visible image contains) but dust and scratches are not, so they show up in the IR channel. This information can then be used to automatically remove the appearance of dust and scratches in the visible channels and replace them with something similar to their surroundings.

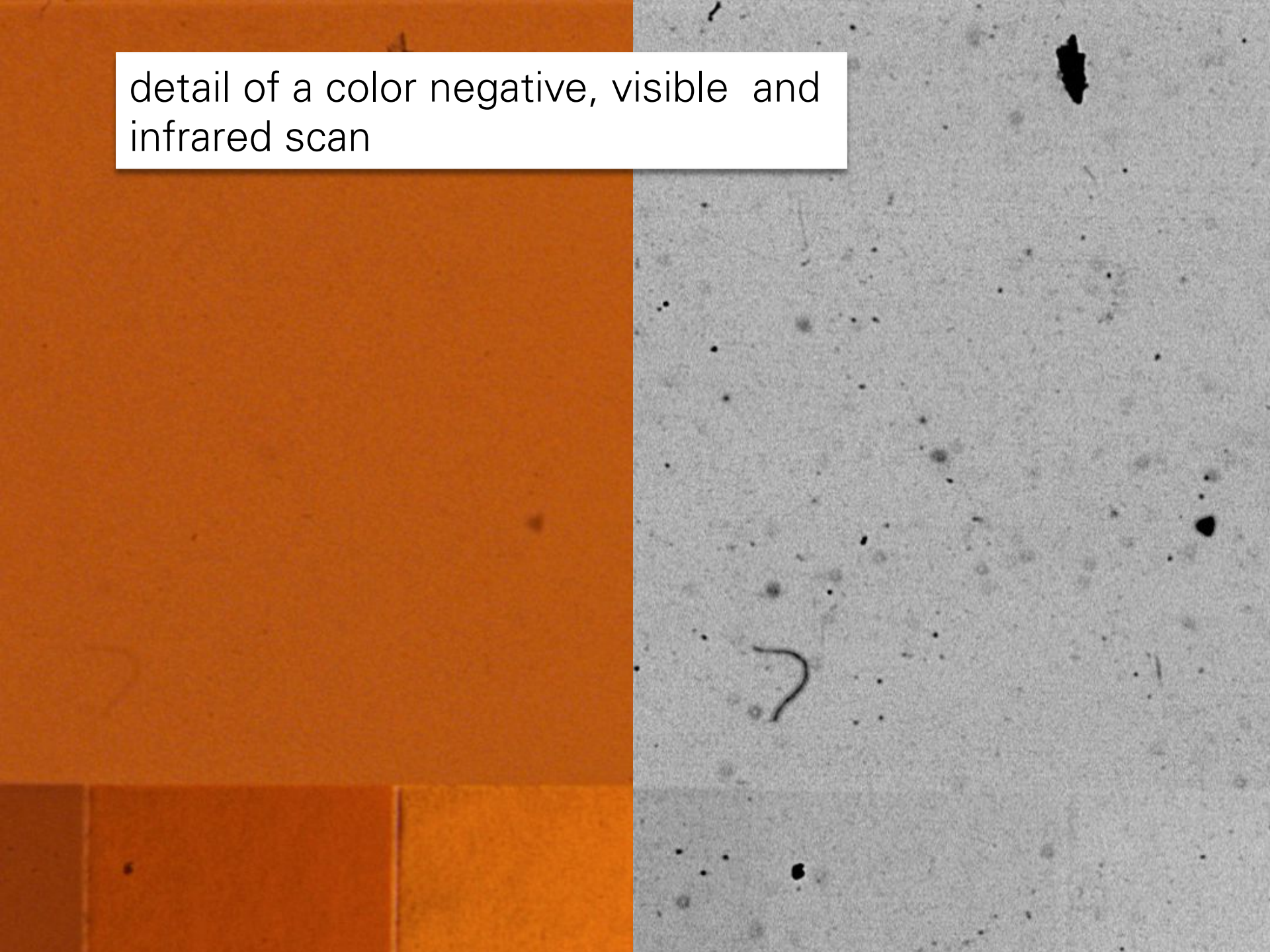
Scanner manufacturers usually have their own name attached to this technique. Kodak developed Digital ICE at their Austin (Texas) development centre. Canon developed its own FARE (Film Automatic Retouching and Enhancement) system.

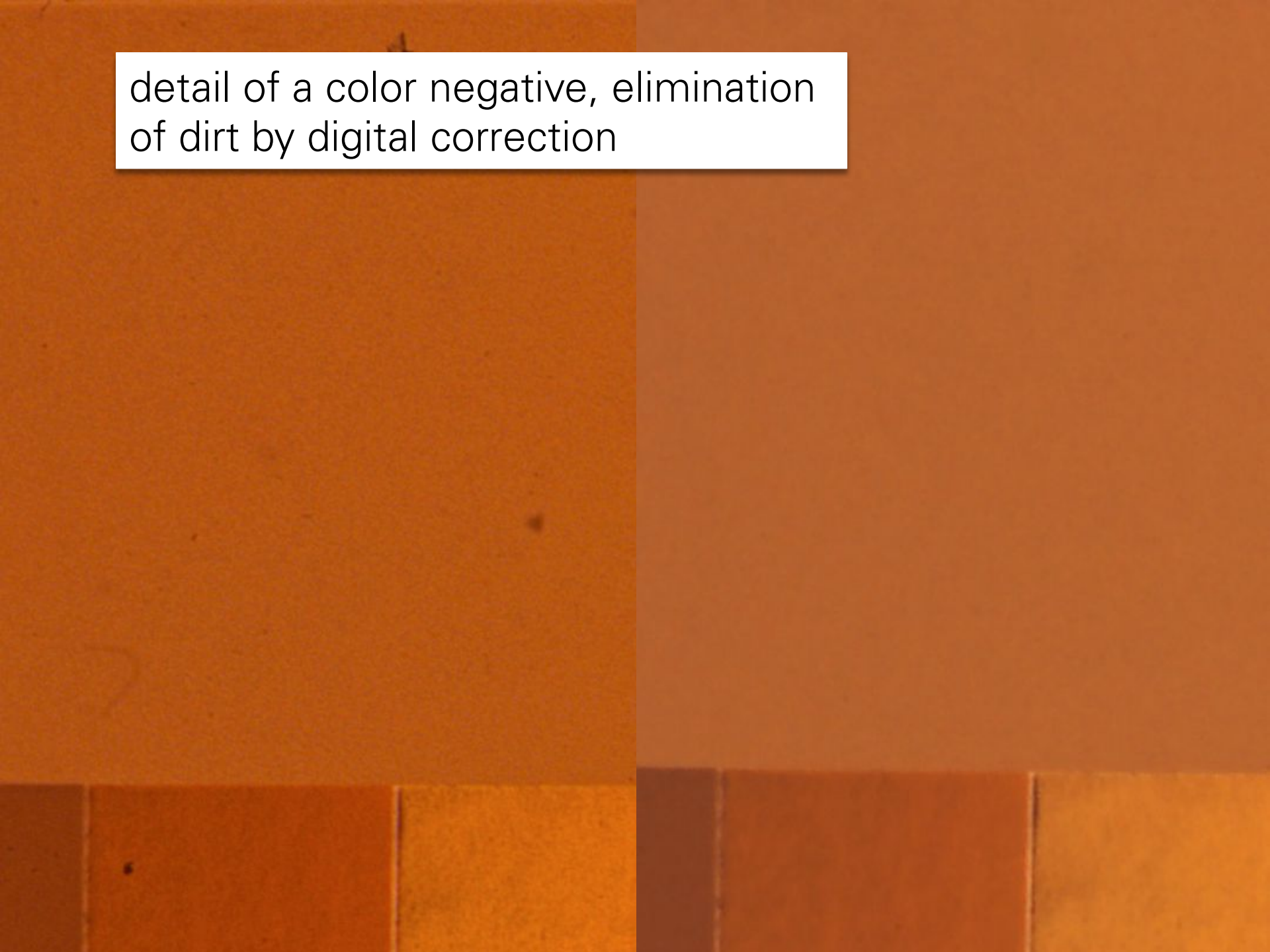
Scan of a color negative, with dirt

Infrared scan of a color negative, only the dirt is visible, the dyes do not absorb in the IR and are “invisible”

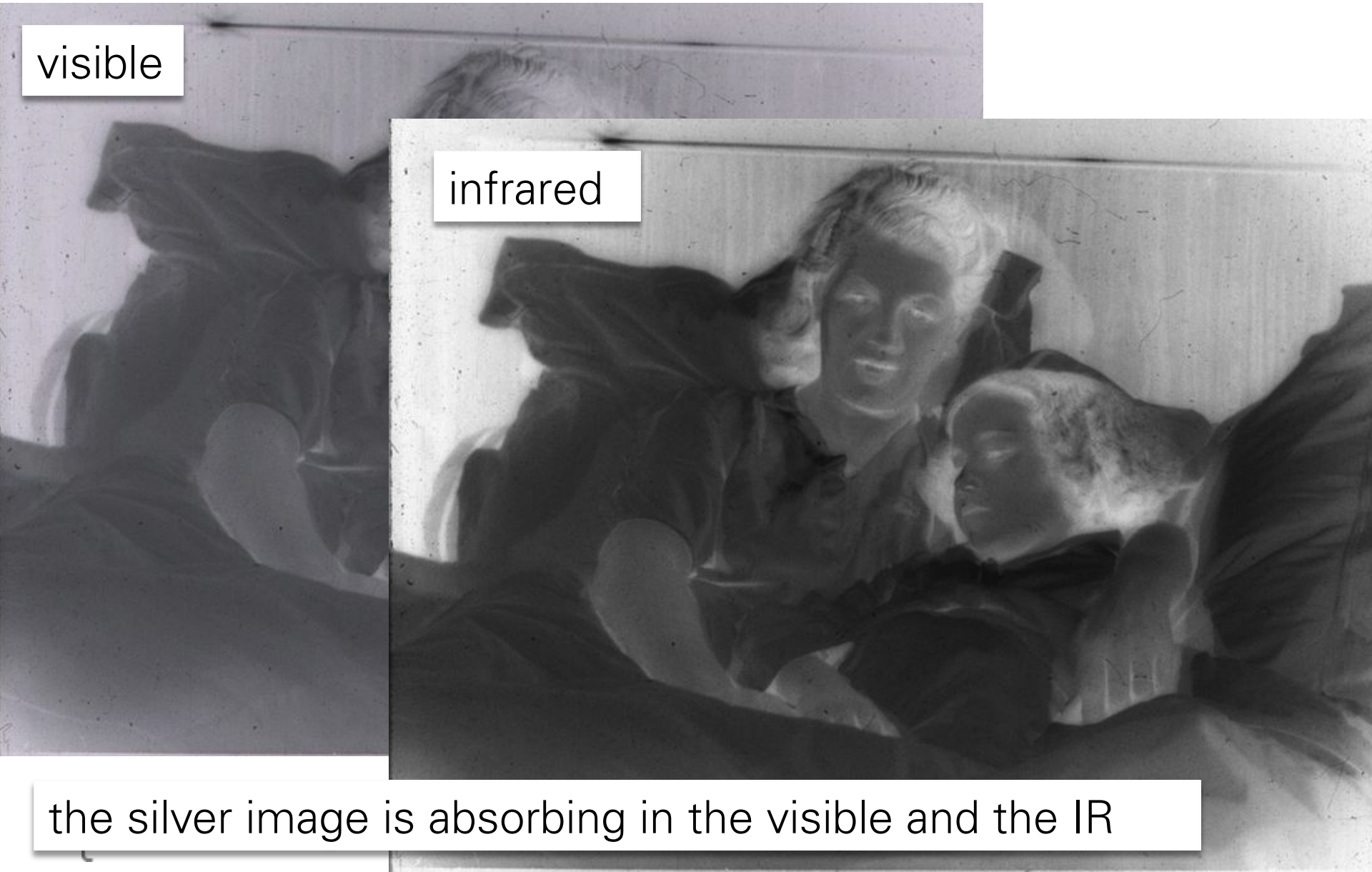

Infrared scan of a color negative
(contrast enhanced)

color negative, elimination of dirt by digital correction

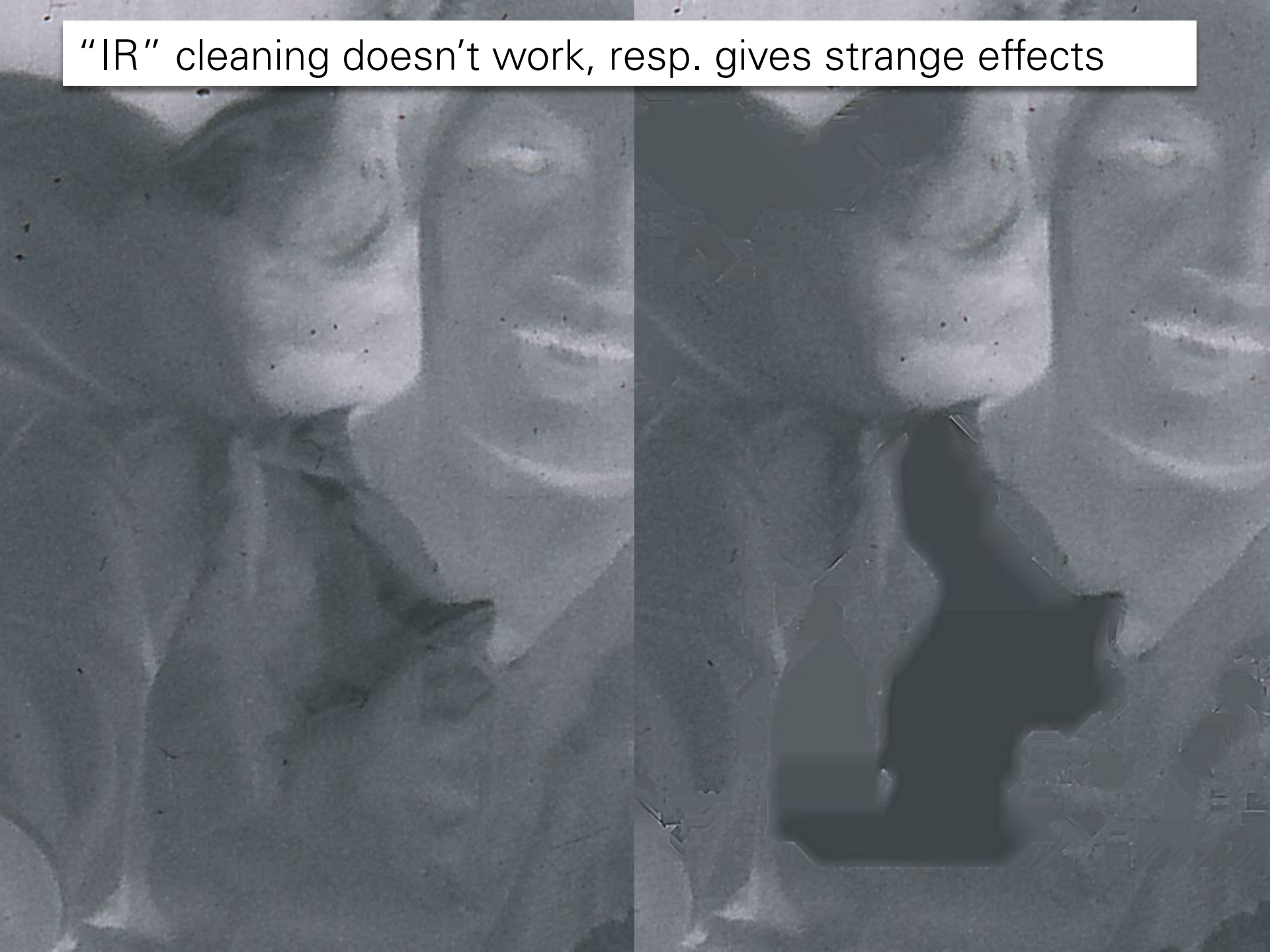

detail of a color negative, visible and infrared scan


detail of a color negative, elimination
of dirt by digital correction

scan of a bw (silver) film

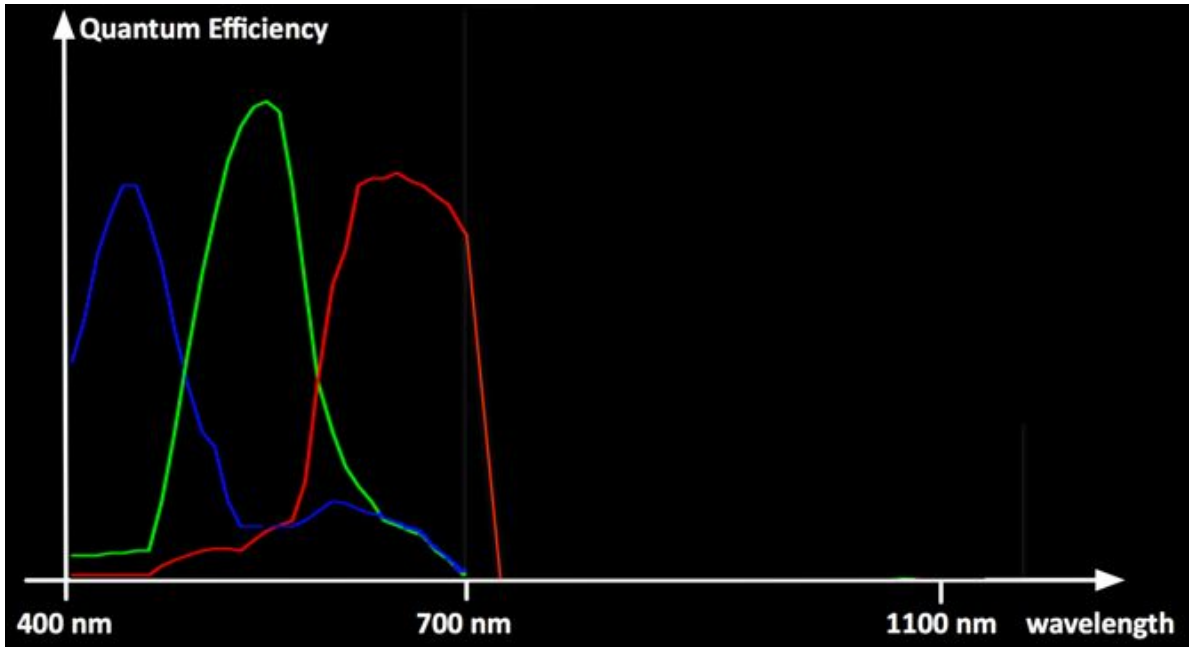


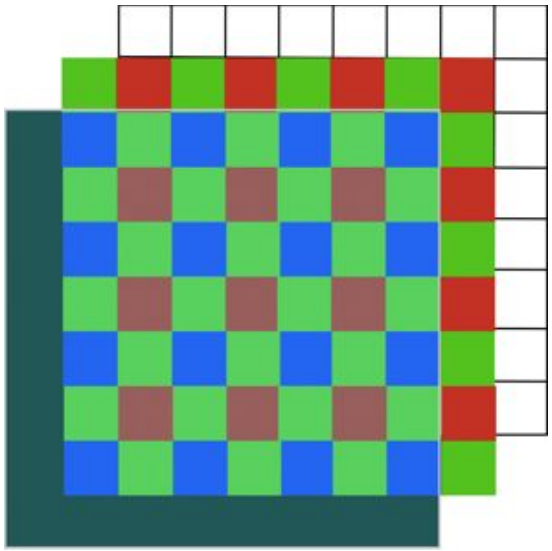
the silver image is absorbing in the visible and the IR


“IR” cleaning doesn’t work, resp. gives strange effects

Another application of using the NIR channel in digital photography

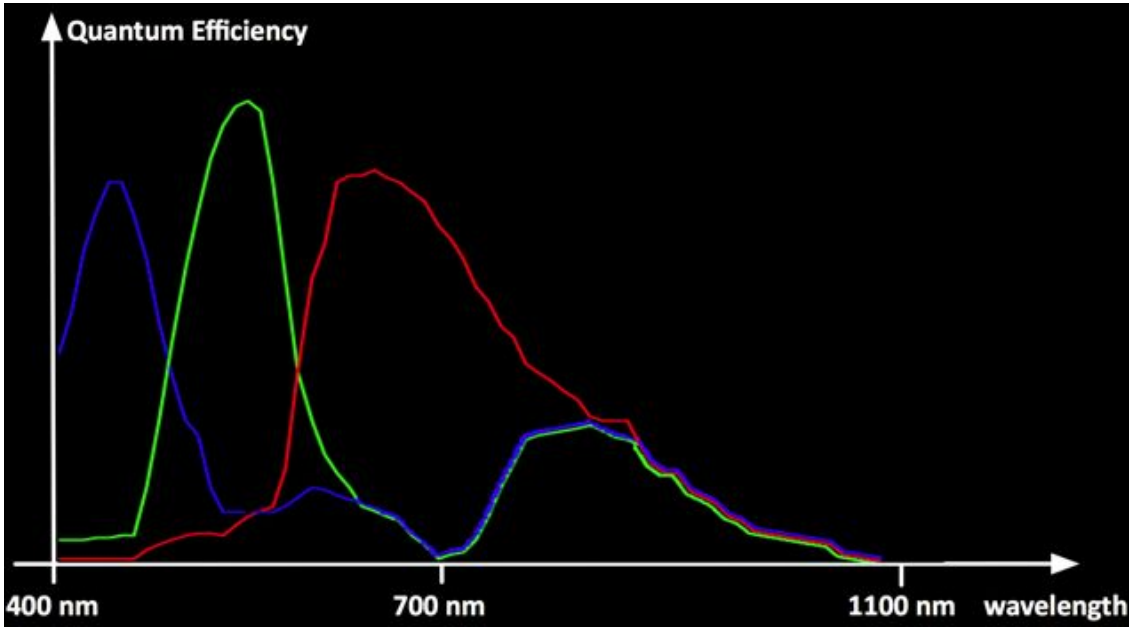
Spectral sensitivity

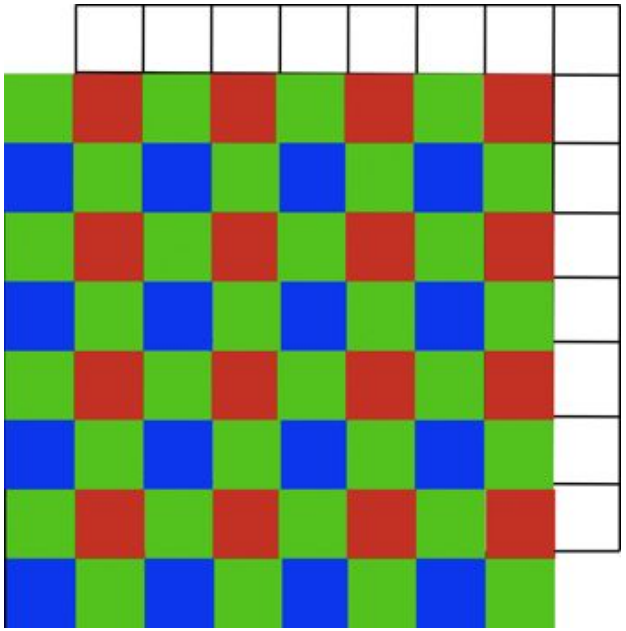




Near Infrared Blocking Filter (Hot Mirror)

Spectral sensitivity WITHOUT Near Infrared Blocking Filter (Hot Mirror)





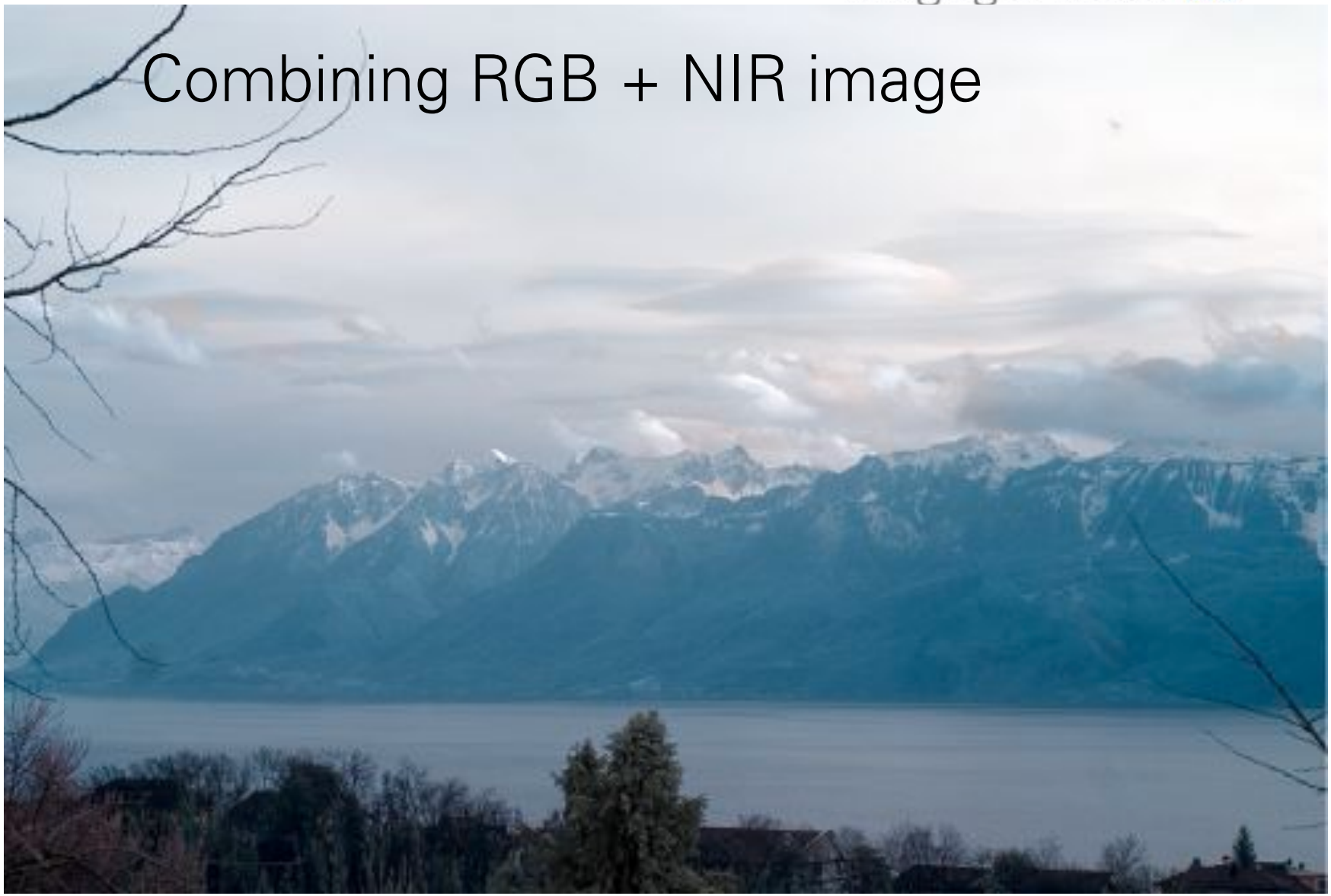
Bayer Color Filter Array (CFA)

visible image

NIR image

Color image dehazing using the Near-Infrared, L. Schaul, C. Fredembach, S. Süsstrunk, IEEE ICIP, 2009.

Combining RGB + NIR image



Color image dehazing using the Near-Infrared, L. Schaul, C. Fredembach, S. Süsstrunk, IEEE ICIP, 2009.

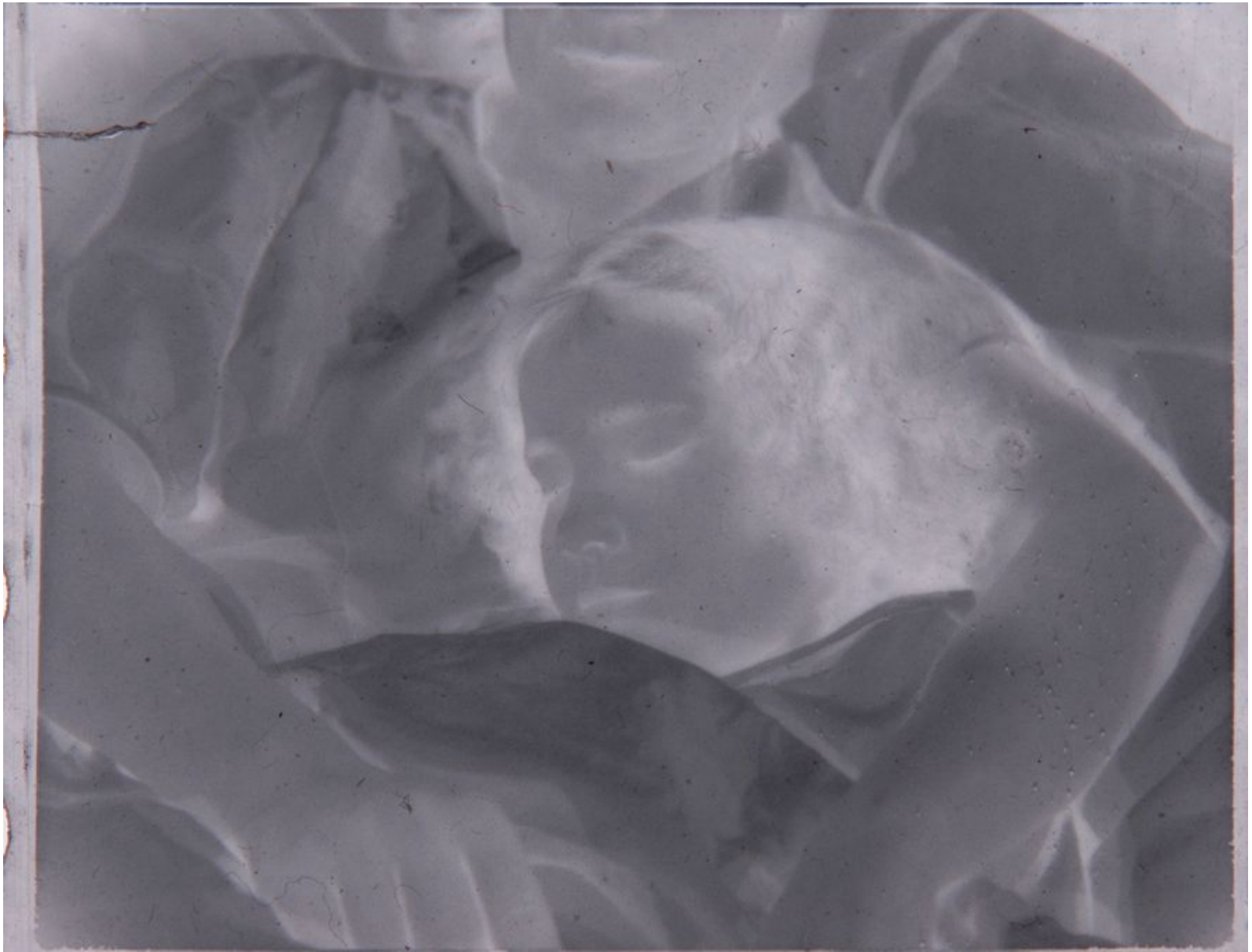
Combining visible and near-infrared images for realistic skin smoothing, C. Fredembach, S. Süsstrunk, IS&T CIC, 2009.

Combining visible and near-infrared images for realistic skin smoothing, C. Fredembach, S. Süsstrunk, IS&T CIC, 2009.

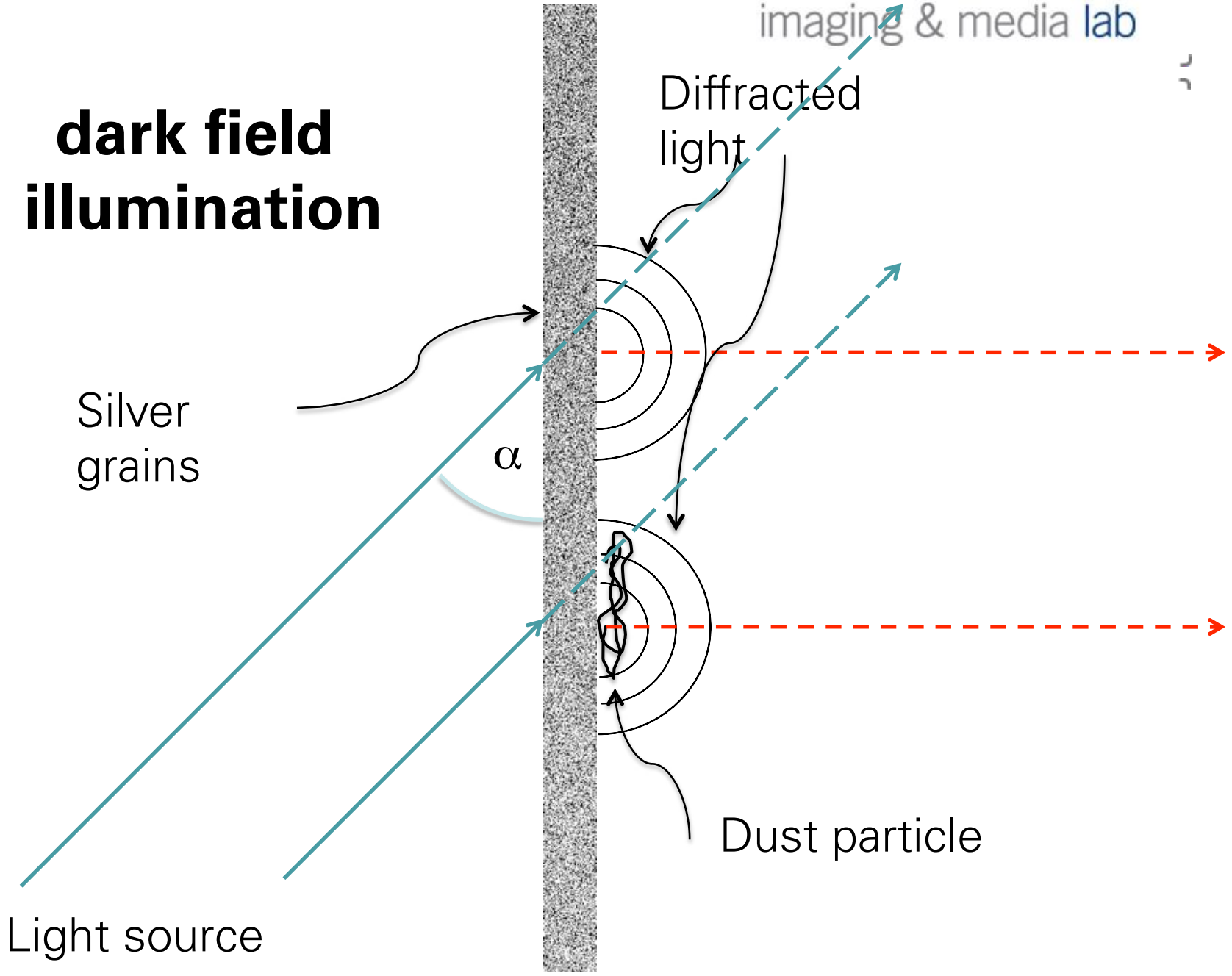
Can we detect dust and scratches on black/white film?

- The IR-cleaning method is not applicable
- From scientific photography and microscopy we know:
  - different illuminations: dark field, reflected light, oblique, bright field, annular or directional
  - use of polarization (linear, circular)

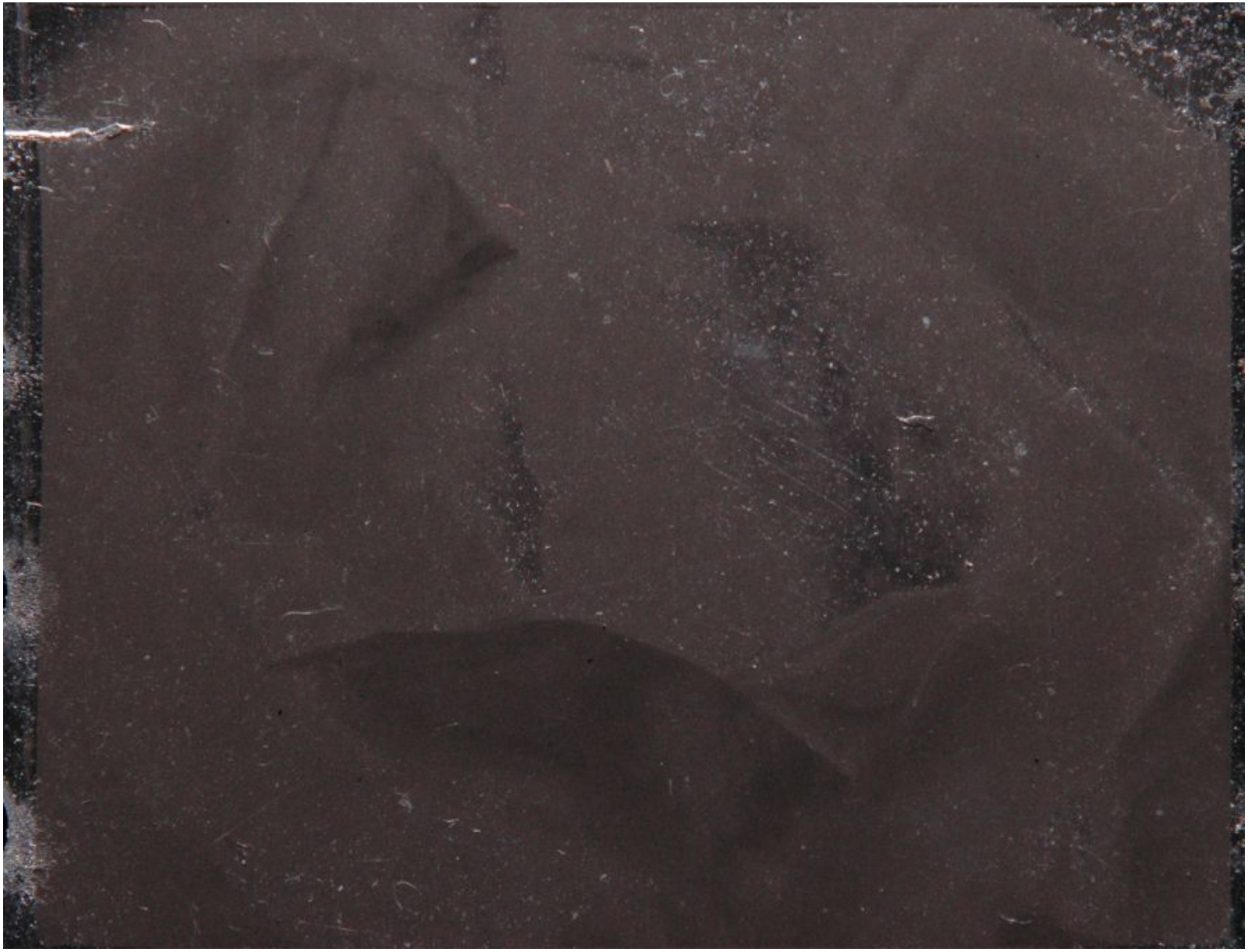
b/w-negative: “normal” transmitted light

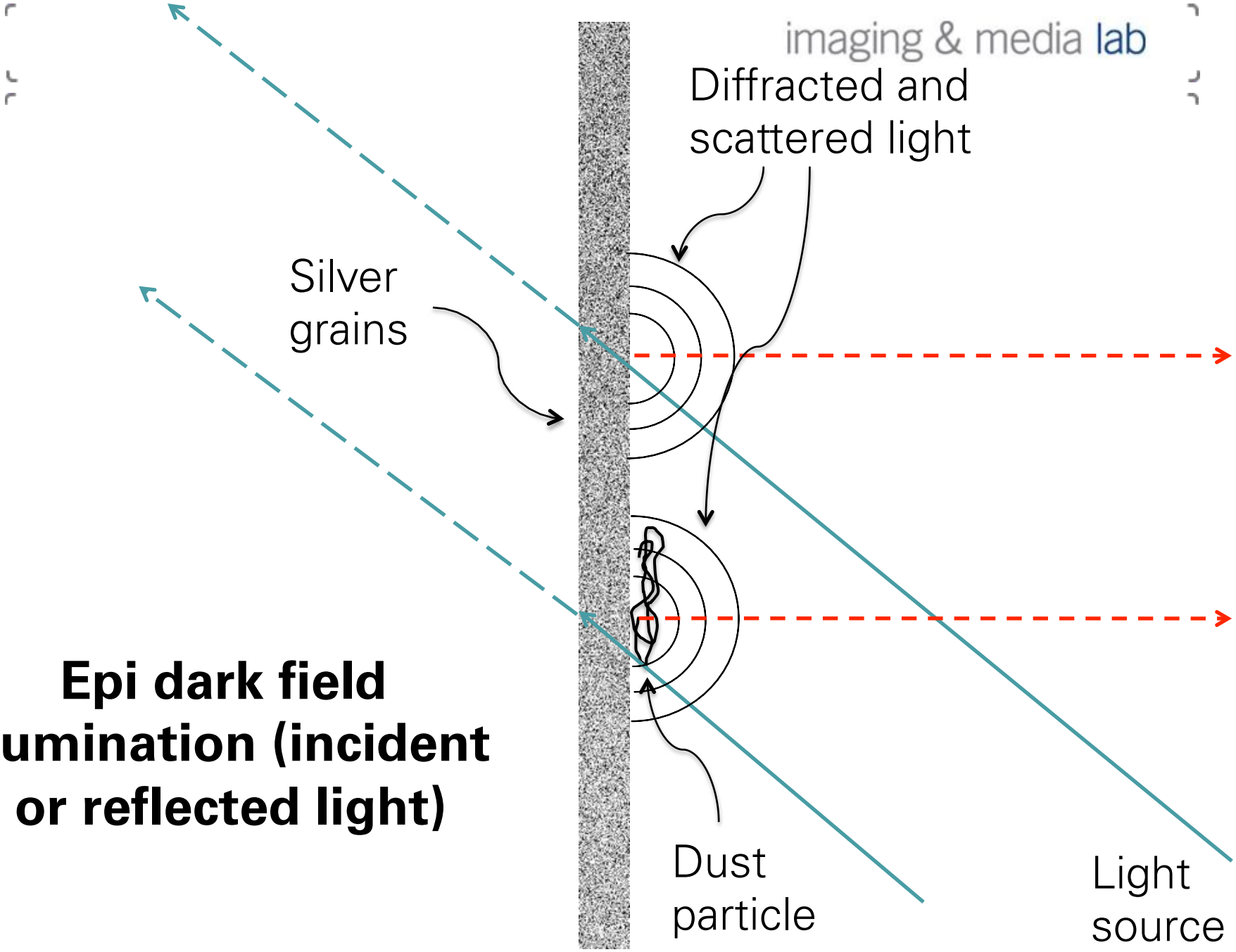


dark field illumination



b/w-negative: dark field



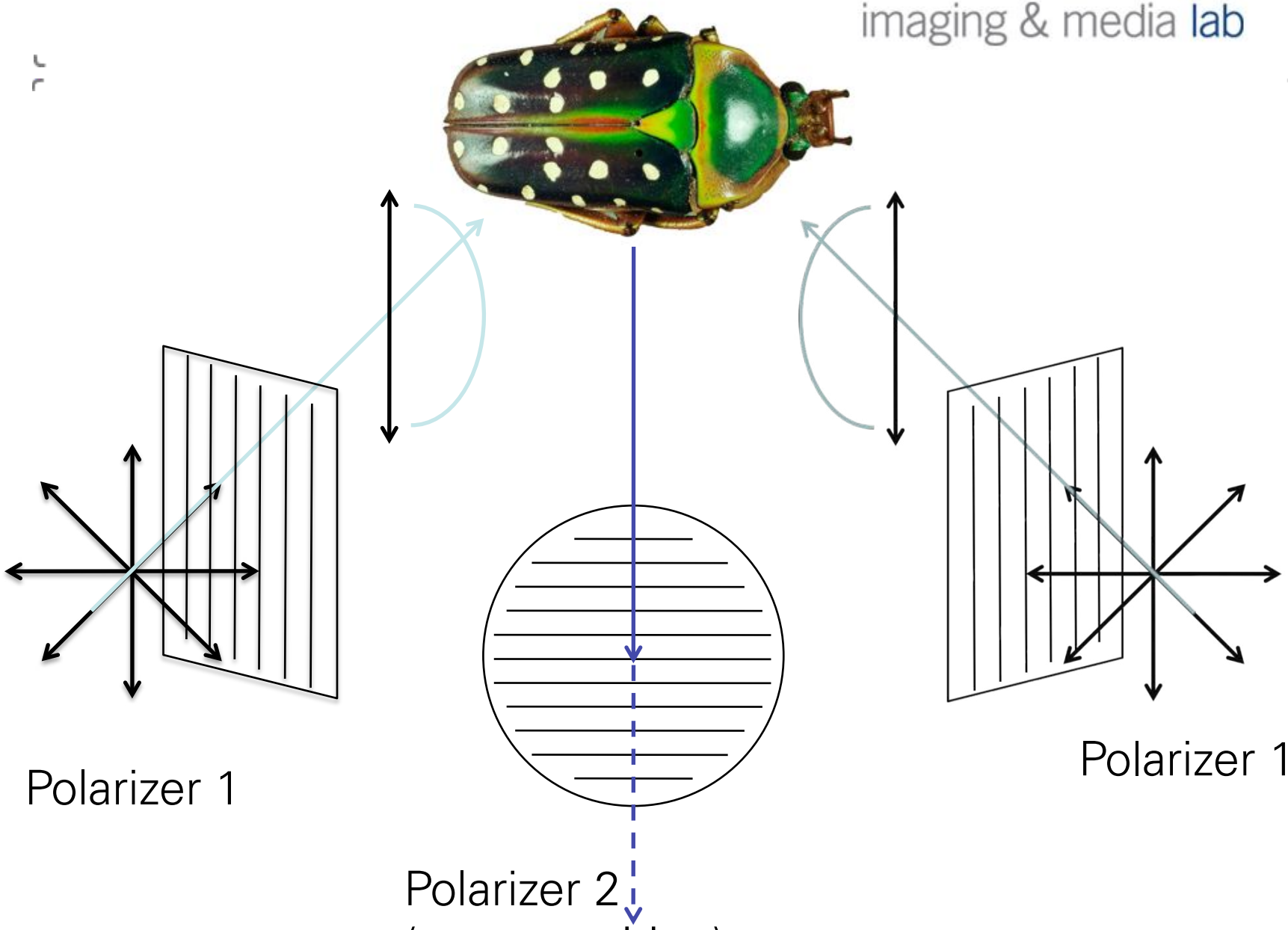


Epi dark field illumination (incident or reflected light)

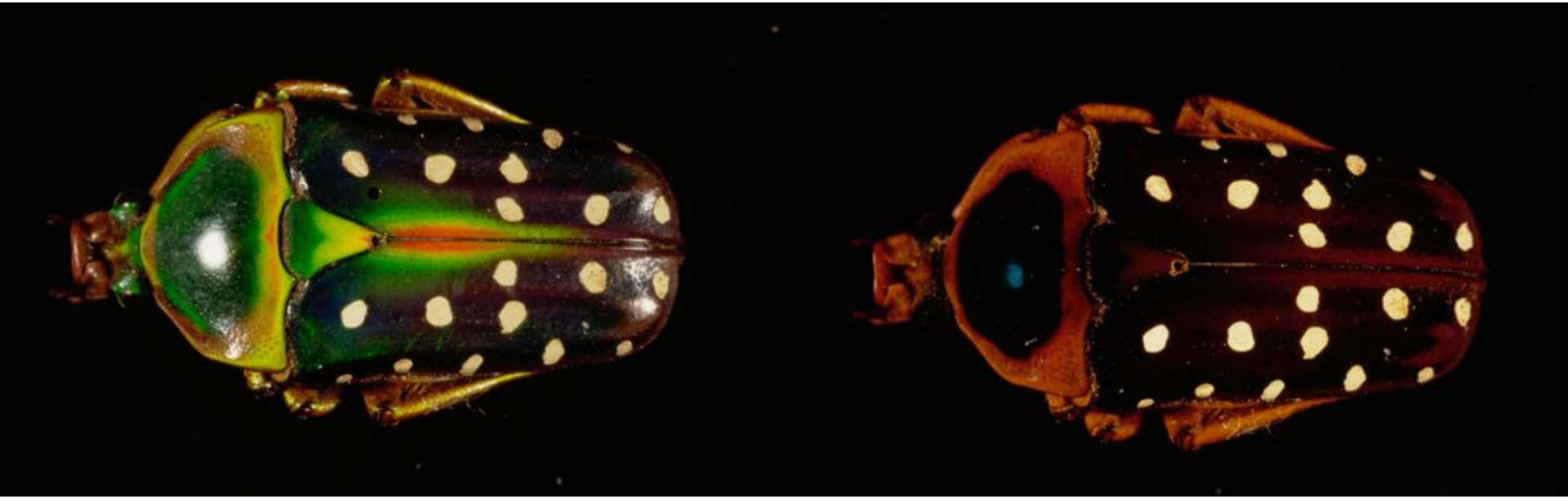
reflected (dark field epi) light

cross polarized illumination

The technique of using polarized illumination and a polarizing filter on the camera (double polarized illumination) is known since long in the scientific photography, especially in the case of reproduction (elimination of gloss and reflections), in dermatology (skin photography) or in microscopy (e.g. metallurgical microscopy)


Polarizer 1
Polarizer 2
(cross position)
Polarizer 1

The example shows the image of a bug (cetonia), once photographed *normally (left), and once photographed by double polarizing (right) illumination*



It is clearly seen that the green and red color on the back results from optical interference phenomena (they can be extinct in double polarizing), whereas the red color of the abdomen and the white spots are due to a colorant

using the same approach on a black-and-white film (an old 35mm movie negative)

The negative image in usual bright field, a detail reveals dark spots, which probably are dust particles

using the same approach on a black-and-white film (an old 35mm movie negative), but now using dark field illumination

If one is looking from the front side without using polarized filters, the light scattered at the silver particles as well at the dust is visible

using the same approach on a black-and-white film (an old 35mm movie negative), but now using dark field illumination

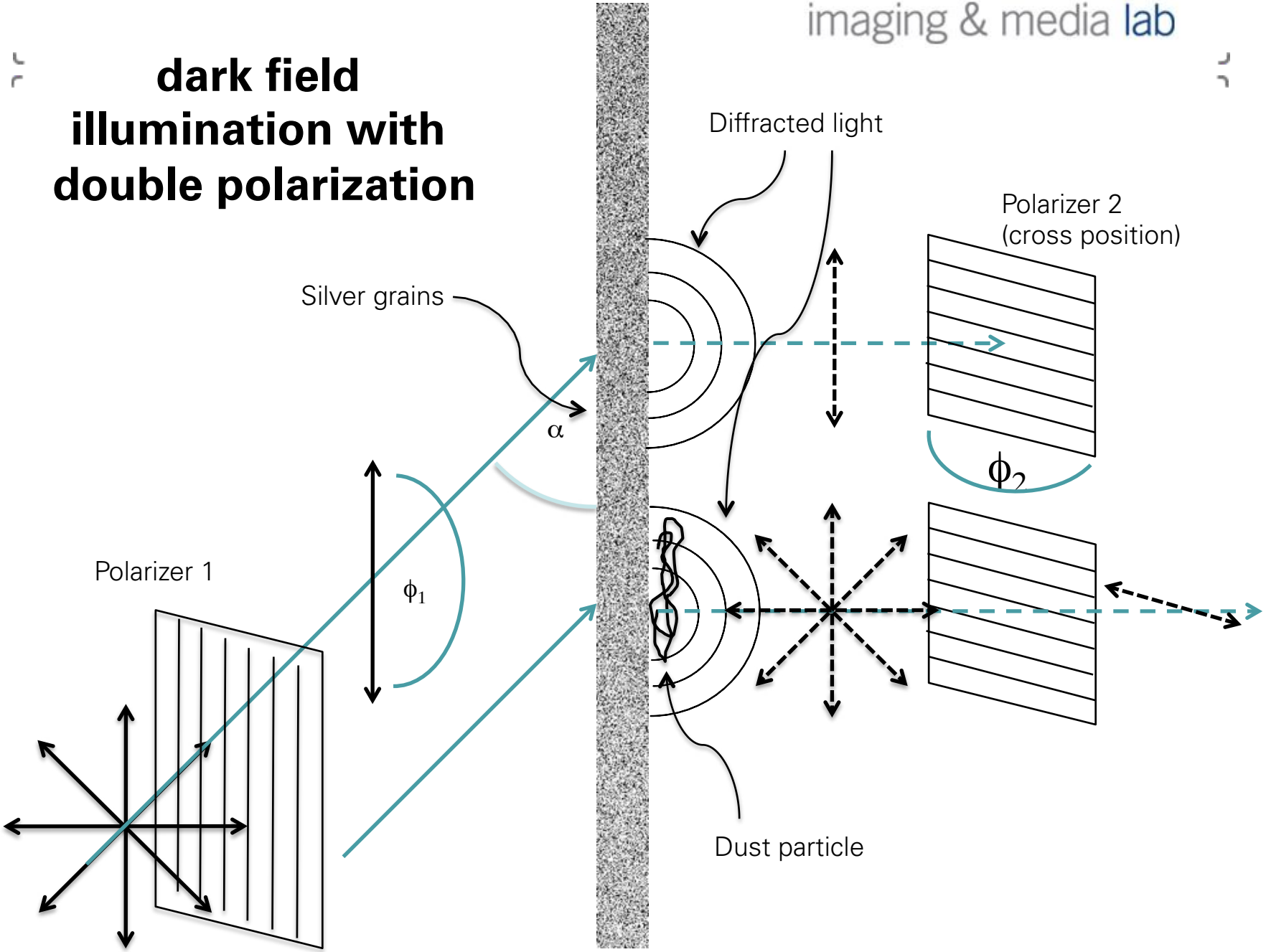
If we now use a **second polarizing filter in cross-position**, the light scattered from the silver particles is blocked, whereas the dust particles are clearly seen

using the same approach on a black-and-white film (an old 35mm movie negative), but now using dark field illumination

If we now use a **second polarizing filter in cross-position**, the light scattered from the silver particles is blocked, whereas the dust particles are clearly seen

contrast enhanced, i.e. the fine grain silver particles do not depolarize the light, whereas much larger dust particles do

dark field illumination with double polarization



Project funded by the Swiss National Science Foundation (start autumn 2010)
Investigations to do

- **Project 1** is the optical, physical and chemical part: the detection of dust and scratches due to scattering phenomena.

- Optical effects
  - Dependence of polarizing angle of the light
  - Dependence on lighting angle
  - Wavelength dependence (visible and infrared)
  - Different illumination geometry
  - Visibility of dust vs. scratches
- Chemical effects
  - Emulsion characteristics, type of film
- Theory
  - Theory of scattering phenomena
  - Computer-Simulation (*Draine, B.T., and P.J. Flatau (1994). "Discrete dipole approximation for scattering calculations".)*
- Scanning
  - Still image
  - Moving image

- **Project 2** is the image analysis part: removal of dust and scratches. The following objectives which will be investigated

- Analysis of existing image restoration/in-painting method
- Threshold (dust/scratch detection or not)
- Removal by in-painting techniques for still images
- Application on moving film (removal by in-painting and motion detection (comparison in the time axis)


Thanks...
any questions?
http://www.iml.unibas.ch
http://ivrgwww.epfl.ch