Introduction to Colour Science

NPGR025

Unit 6: Colour Reproduction

Computer Graphics Charles University

Sources:
Kipphahn, Handbuch der Printmedien
The Web

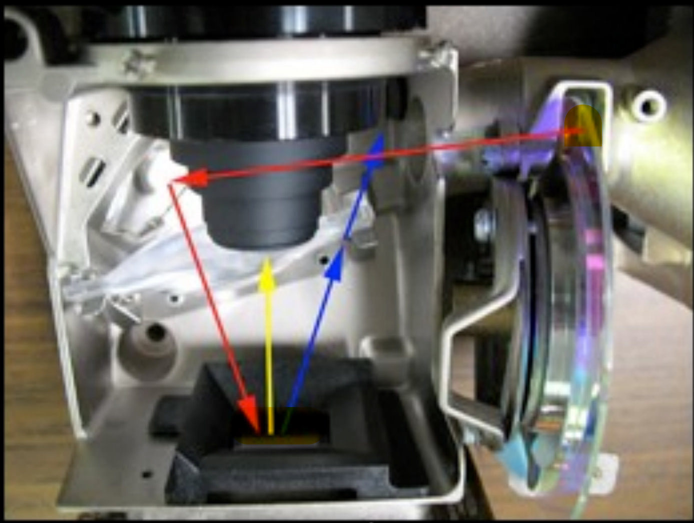
Overview

- Additive: Self-Luminous Display technologies
- Additive: Photographic film
- Gamut mapping
- Subtractive: Printing technology
  - Inkjet
  - Laser
  - Offset

Self-Luminous Displays

- Cathode ray tubes
  - Good colour constancy
  - Bad ergonomic properties
- Liquid crystal displays
  - Comparatively bad colour performance
  - Good ergonomic properties
- Beamer devices
  - Limited use, good possibilities

DLP Beamer Anatomy



DLP Beamer Anatomy

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Photographic Film

- Invented in the early 19th century – limited to black and white
- Colour photography started to be practically useable in the late 1930ies (exceptions prove the rule)
- Use for imaging purposes is limited
- Slide printers used to be common, niche applications still exist

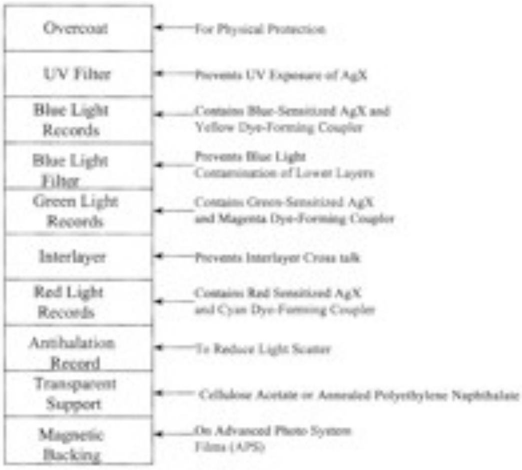
Primitive Colour

- Uses 3 negatives and red, green & blue filters

- Used e.g. in Russia ~1910
- Difficult reproduction on devices of the day
- http://www.loc.gov/exhibits/empire/

Colour Film Principle

- Treated AgX used as light-sensitive compound
- Several layers of differing sensitivity responsible for different colours



Colour Film Properties

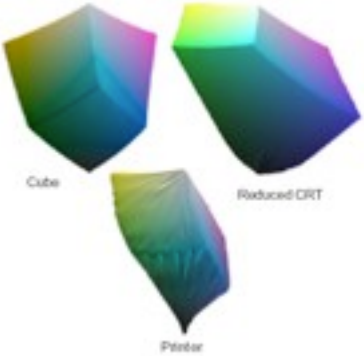
- Advantages:
  - Slides have high contrast ratio and good colour gamut
  - Very durable form of output
- Disadvantages:
  - Processing required (for slides: projector)
  - Film gamut limited to gamut of slide writing equipment
- Nowadays only useful for niche applications

Subtractive Colour Mixing

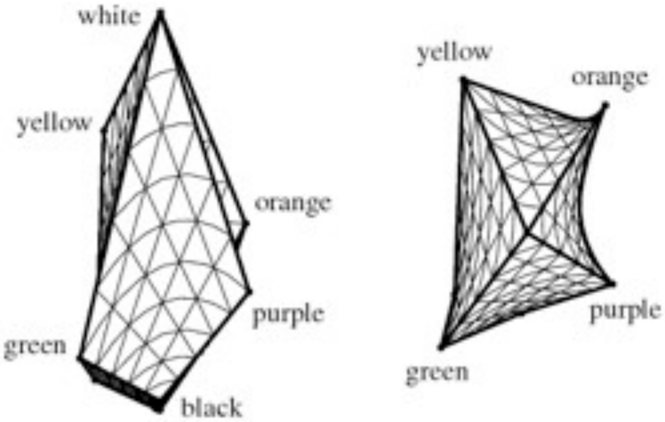
- Basic colours for subtractive colour models are usually cyan, magenta and yellow
- Gamut of CMY is usually substantially smaller than the RGB gamut and very non-linear in L
- In order to improve the printing process, black (=key in printer jargon) is usually added, which leads to the CMYK colour space

Display Gamuts

- If similar appearance is desired across varying output devices, some kind of corrective mapping has to be applied
- For colour space compensations, this mapping is known as **gamut mapping**



Subtractive Colour Gamut

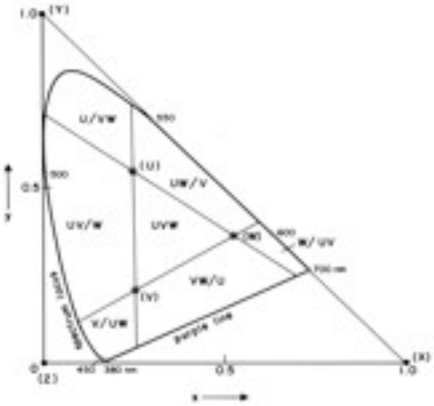


Gamut Mapping Strategies

- Global vs. Local
- Global methods preserve overall appearance of image
- Local methods introduce less distortion by just treating the out-of-gamut pixels

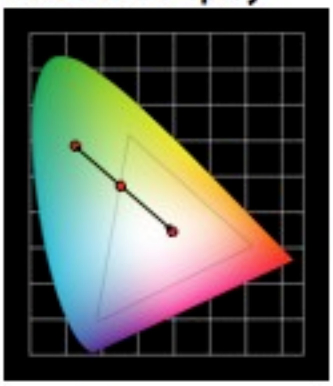
Tristimulus Colour Mixing

- Separation of x,y space into areas that can be described by particular mixtures of UVW
- Left of dash = positive
- Right of dash = negative



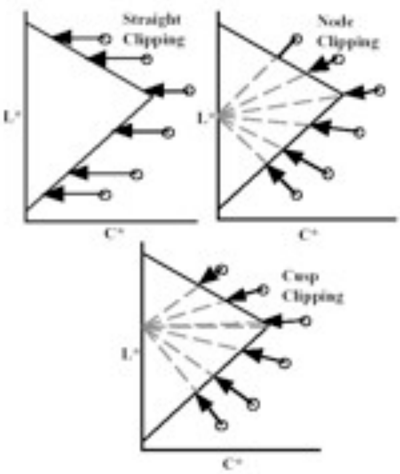
Gamut Mapping – Chroma

- Gamut mapping in chroma space just requires one to move the offending colour inside the display gamut
- Direction: usually towards the white point
- Fast iterative process
- Issues:
  - real gamuts are not 2D
  - and not linear, either



Gamut Clipping Strategies in L

- Straight clipping preserves luminance, but loses chroma information
  → artificial highlights
- Other two methods tend to lose highlight information resp. generate uniform patches



Gamut vs. Tone Mapping

- The two terms essentially mean the same thing
- The proper expression for both is tone reproduction operators
- Common differentiation:
  - Tone mapping is used for situations where the luminance values are far out of range (photorealistic computer graphics)
  - Gamut mapping is done in situations where colour gamut problems prevail (printing industry)

Pantone Hexachrome

- Industrial standard for larger gamut (offset) printing defined by Pantone

- Also known as CMYKGO, for Cyan Magenta Yellow Key Green Orange

Hexachrome Properties

- Advantages:
  - Exceeds RGB gamut everywhere except in the green area – superior colour rendition
  - Can save money if spot colours are no longer needed
- Disadvantages:
  - More costly during setup
  - Requires special software and printing presses

6 or 7 Colour Inkjets

- Modern consumer-level photo printers also use 6, or sometimes even 7, inks
- Key difference: the inks are
  - Dark and light cyan
  - Dark and light magenta
  - Yellow
  - (Dark and light black) or just black
- The overall gamut does not get bigger, but drop mixing artefacts are reduced

Inkjet Printers

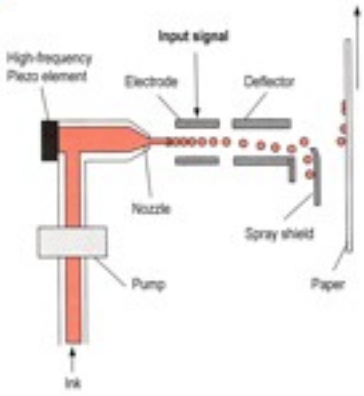
- Basic idea: small drops of ink are individually sprayed onto the paper to form an image
- Advantages:
  - Simplicity
  - Low cost of device
- Disadvantages:
  - Speed
  - High cost per page
  - Durability of result

Inkjet Printer Types

- Continuous ink jet devices
  - Comparatively rare, used for high-speed devices
- Drop-on-demand technologies
  - Thermal/bubble jet devices
  - Piezoelectric device
- All types are prone to drying problems when heads with fine resolution are used (photo printers)

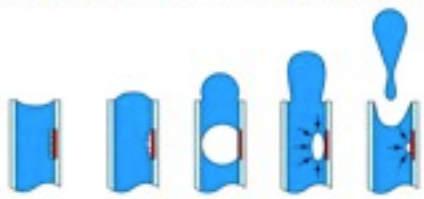
Continuous Ink Jet

- Electrostatic deflection is used to modulate travel of continuous, high-frequency beam of droplets onto target

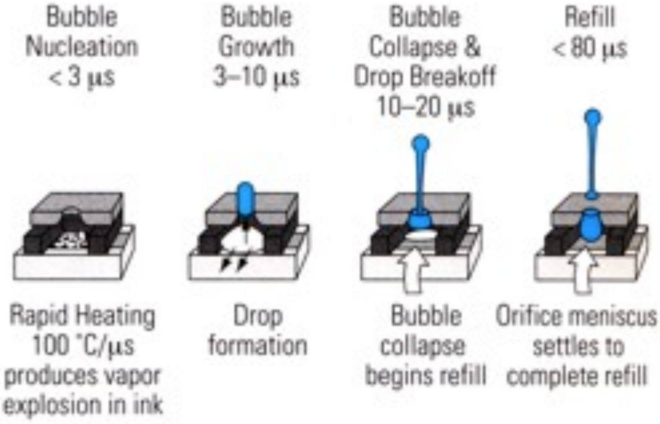


Bubble Jet (HP, Canon)

- Small thermo element causes rapidly expanding bubble in ink channel
  → ink droplet gets ejected
- Reliable and reasonably fast
- Hard to miniaturise beyond a certain level
- Temperatures can lead to problems with head durability

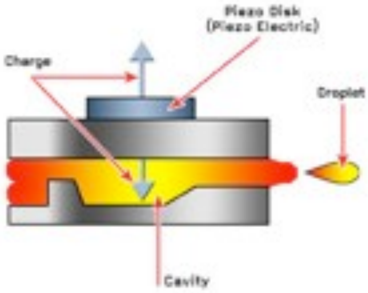


Bubble Jet Cycle



Piezo Heads (Epson)

- Long time to market, but superior to thermal heads (better resolution)
- Actual print head more expensive than thermal version



Inkjet Ink Requirements

- Viscous (so that heads will work)
- Shallow paper penetration (so paper is not softened & dots remain sharp)
- Deep paper penetration (so that ink dries fast & colours are deep)
- Little dot bleed when mixed
- Lightfast
- Non-toxic and non-flammable

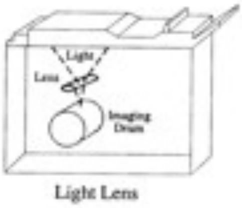
Inkjet Material Taxonomy

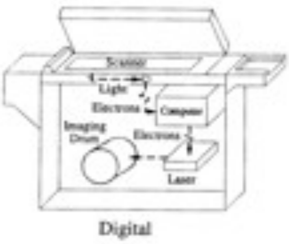
Laser Printers

- Digitally controlled electrostatic printers
- Advantages:
  - Fast
  - Low cost per page
- Disadvantages
  - Expensive (especially colour devices)
  - Slightly reduced gamut
  - Not capable of any additional colours

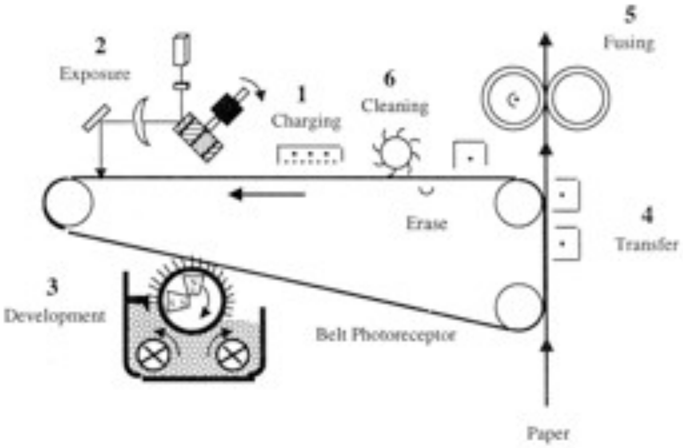
Electrostatic Printing

- Invented in 1938
- Used in analog optical copiers for decades
- Digital devices appeared in the 1970ies
- The term "Laser printer" is derived from the infrared imaging lasers used



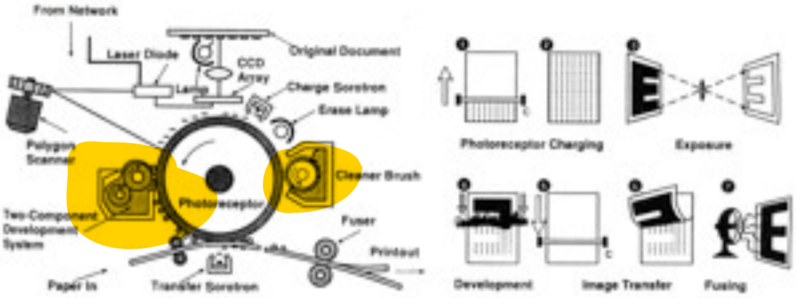


Electrostatic Printing #1

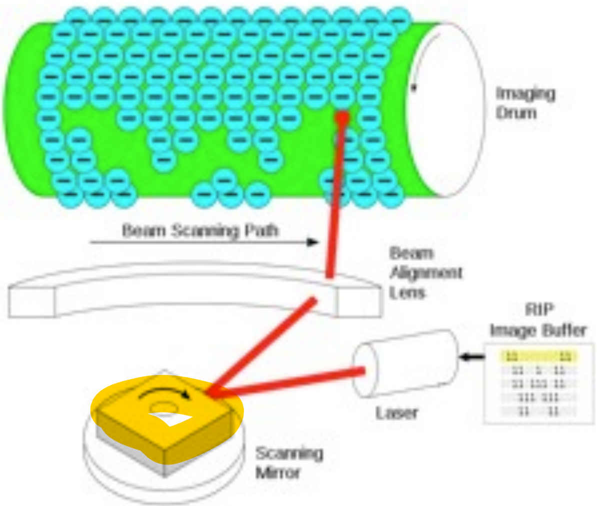


Electrostatic Printing #2

- Process basically unchanged since 1938
- No differences between copier and printer imaging engines

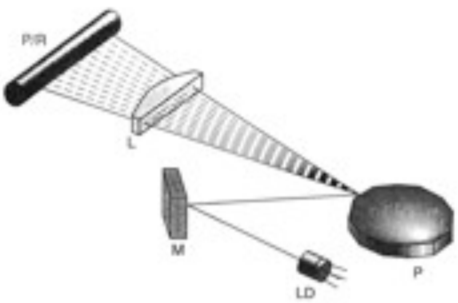


Laser Imaging Principle



Typical Imager Unit

- Key components:
- Rapidly addressable laser diode (usually IR)
- Rotating mirror (30000 rpm)
- Lens system
- Beam discharges single points on imaging drum

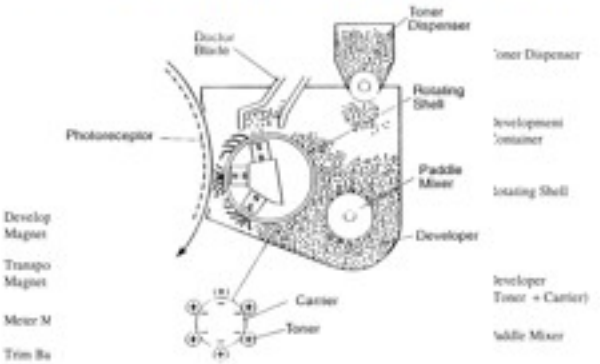


Imager Unit Variations

- Laser diode drawbacks:
  - Dot non-uniformity across line
  - Several units needed for high performance
- Alternative: LED bars
  - Advantage: fast, good for wide printers
  - Disadvantages:
    - Single dead LED kills whole component
    - Non-uniformity of luminance

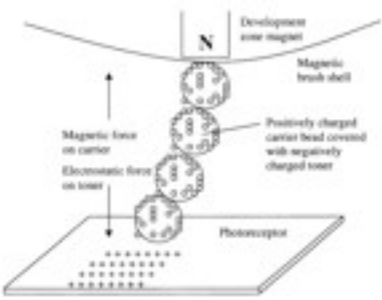
Two Component Developers

- Original Xerographic process
- Still used in high-quality, high-speed devices



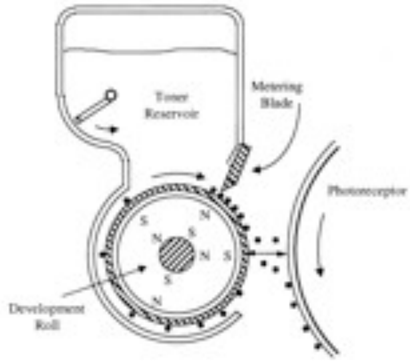
Two Component Developers

- "Brushes" are formed by magnetic beads and used to deposit electrostatically charged toner particles on the paper



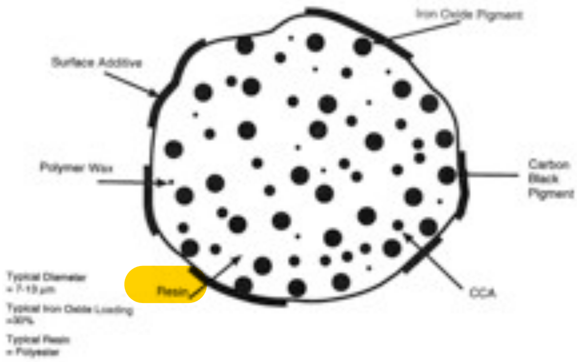
Single Component Developers

- Newer development
- Used in slower, cheaper machines



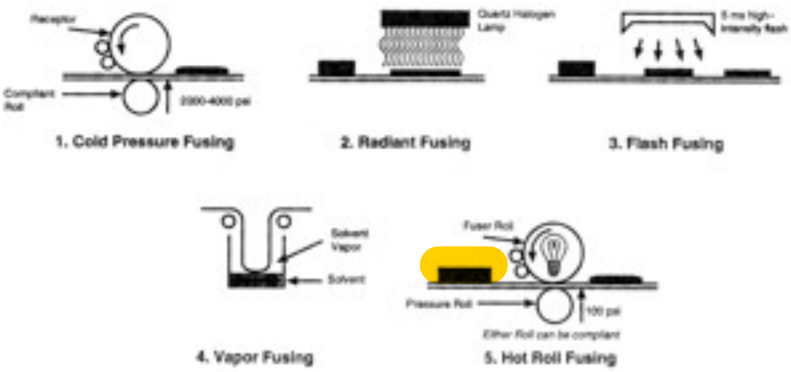
Laser Printer Toner

- Typical property: solid pigments are used as colorants

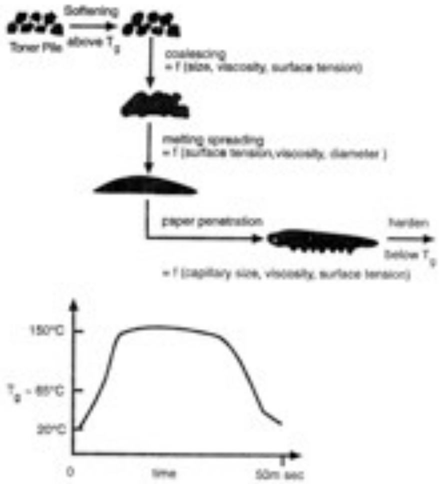


Laser Printer Toner Fusing

- Method used depends on toner particle, cost and speed issues



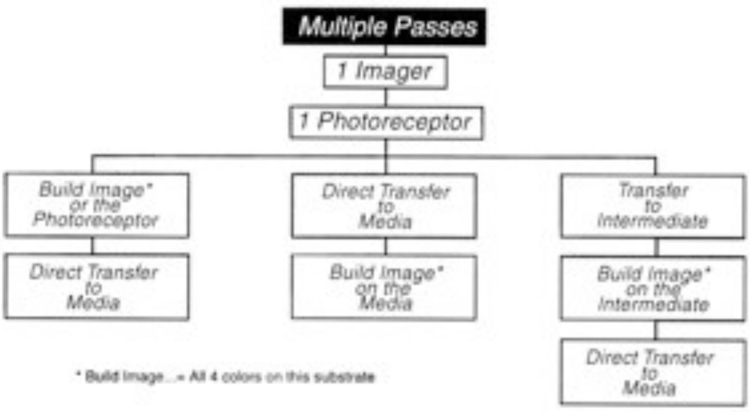
Toner Fusing Process



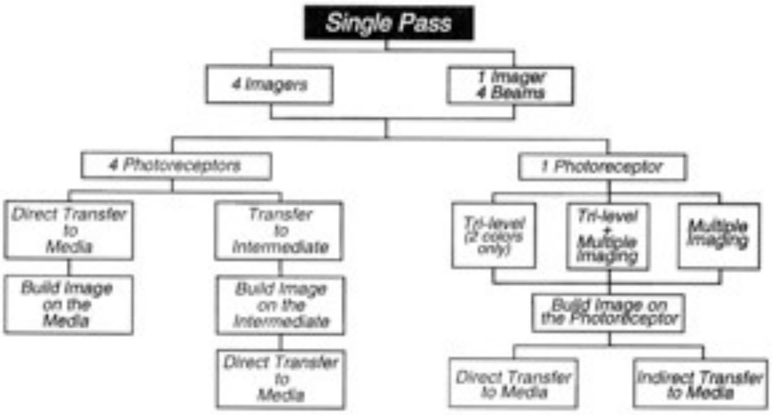
Laser-Based Colour Imagers

- Huge variety of devices exists
- Reasons for variety:
  - Speed/cost tradeoffs
  - Patent issues
- Common to all types:
  - Somewhat reduced colour gamut when compared to ink-based systems
  - Glossy finish of toners
  - Durable output

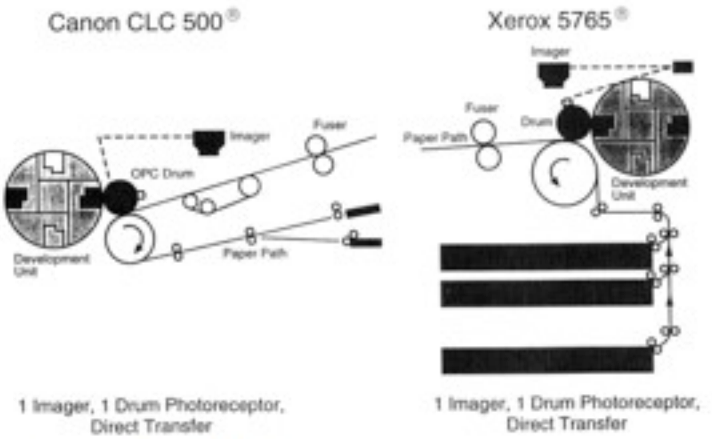
Colour Laser Taxonomy #1



Colour Laser Taxonomy #2

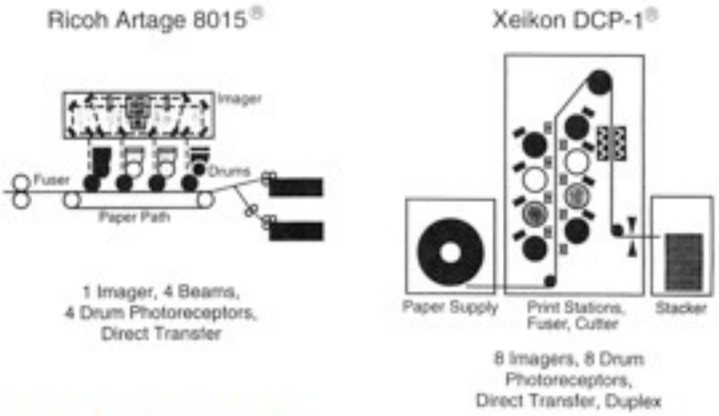


Colour Imager Examples #1



- "Lower end" machines

Colour Imager Examples #2



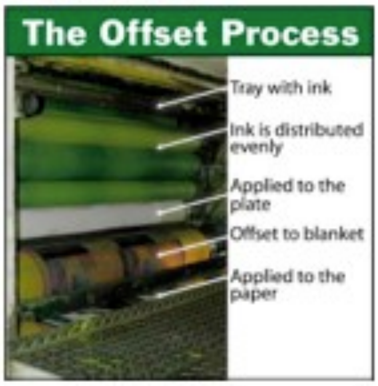
- Higher end machines

Specific Example: Xeikon DCP500

- LED-Array imaging
- 130 A4 pages/min
- 600dpi
- 47cm imaging width
- Roll feed
- One-pass duplex
- Much faster turnaround times than plate-based printing machines

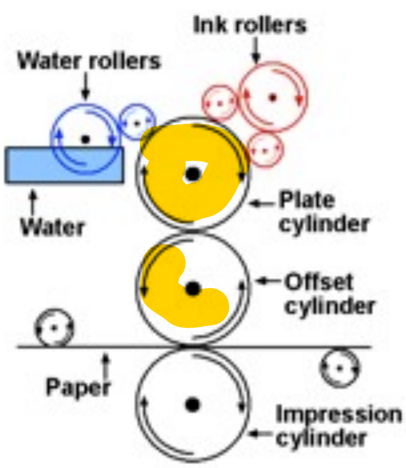
Offset Printing

- Basic principle: oil and water do not mix
- Offset plates do not contain any grooves
- Photographically pre-pared plates attract oily inks in dark areas
- Water is applied to all other areas
- Inks are transferred to paper via an inter-mediate roll



Offset Details

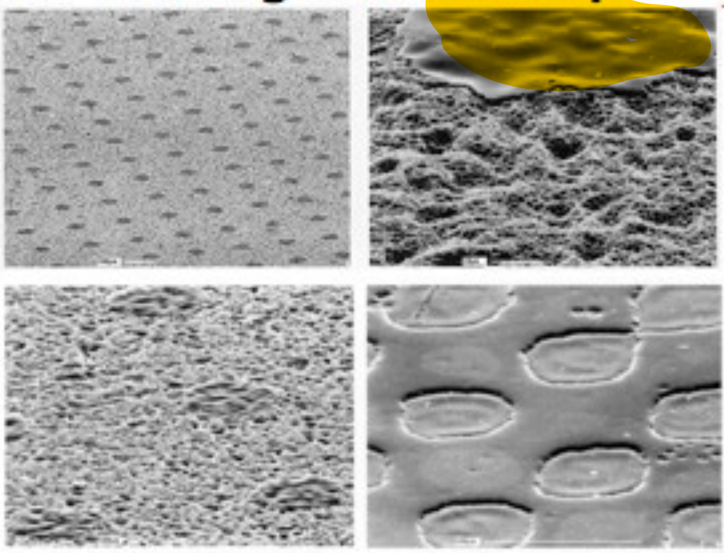
- Purpose of offset cylinder: improved print quality
- Modern machines operate without water (special inks and plates)



Offset Plate Preparation

- Prior to printing, plates of all pages have to be produced
- For colour pages, four plates have to be imaged
- Aluminium sheets are best carrier material
- Phototypesetters used have ultra high resolution (>2500 dpi)

Printing Plate Closeups



Offset Production Process

- After preparation, plates have to be mounted in press
- Only roll feed paper is used
- Advantages: extreme speed, excellent gamut, low per-page-cost, possibility of including custom inks and finishes
- Disadvantages: (high equipment cost), high setup costs, not practicable for small runs

Small Offset Example: Xerox DI400

- Up to 400 pages per minute (b/w & c)
- Plates are imaged in the press directly from digital data
- Max. 2450 dpi resolution on up to .4mm paper
- 4 or 5 colours possible
- Special ink types can be used (e.g. Metallic)
- Weight: 9 tons for 5 roll version