Comparing Under-Display Camera Technology Across Brands

Description

Comparing Under-Display Camera Technology Across Brands: A Detailed Analysis

Introduction

Under-display camera (UDC) technology represents one of the most significant advancements in smartphone design, aiming to eliminate the notch, punch-hole, or pop-up mechanisms that disrupt full-screen experiences. By embedding the front-facing camera beneath the display, manufacturers seek to deliver a seamless, uninterrupted viewing area while maintaining high-quality selfies and video calls.

However, implementing UDC technology presents substantial challenges, including maintaining display clarity, preserving camera performance, and ensuring durability. Different brands have adopted varying approaches, each with distinct trade-offs in terms of image quality, display transparency, and overall user experience.

This article provides a comprehensive comparison of under-display camera technology across leading smartphone brands, examining their methodologies, performance, and real-world implications.

The Evolution of Under-Display Camera Technology

Before diving into brand-specific implementations, it is essential to understand the fundamental principles of UDC technology. Traditional smartphone displays use opaque layers to house pixels, making it impossible to place a camera beneath them without obstructing the sensor. To overcome this, manufacturers have developed specialized display panels with:

1. **Transparent Pixel Regions** â?? A small section of the display is modified to allow light to pass through to the camera sensor.
2. **Low-Pixel Density Zones** â?? The area above the camera has fewer pixels per inch (PPI) to improve light transmission.
3. **Advanced Algorithms** â?? AI and computational photography techniques enhance image quality degraded by the display layer.

Despite these innovations, early UDC implementations suffered from visible camera zones, reduced brightness, and poor image quality. Recent advancements have significantly improved performance, though challenges remain.

Brand-by-Brand Comparison of Under-Display Camera Technology

1. ZTE: The Pioneer of Under-Display Cameras

Models: ZTE Axon 20 5G, ZTE Axon 30 5G, ZTE Axon 40 Ultra

ZTE was the first company to commercially release a smartphone with an under-display camera, debuting the **Axon 20 5G** in 2020. Their approach has evolved with each iteration, refining both display clarity and camera performance.

Technical Implementation

- **First-Generation (Axon 20 5G):**
- Used a **360Hz high-frequency PWM dimming** display to reduce flicker.
- The UDC zone had a **lower pixel density (200 PPI vs. 400 PPI in the rest of the display)**.
- Visible camera area due to **diffraction and light scattering**.

- **32MP front camera** with software enhancement.

- **Second-Generation (Axon 30 5G):**

- Improved **transparency with a new pixel arrangement** (400 PPI in the UDC zone).
- **Smaller camera area (2.2mm vs. 3.8mm in Axon 20)**.
- **64MP front camera** with better low-light performance.

- Reduced visibility of the camera zone under normal lighting.

- **Third-Generation (Axon 40 Ultra):**

- **Dual-layer display stack** to improve light transmission.
- **Higher transparency (40% improvement over Axon 30)**.
- **60MP front camera** with **AI-based image processing**.
- **Near-invisible camera zone** when the display is on.

Performance & Trade-offs

- **Pros:**
- First to market, proving UDC feasibility.
- Continuous improvements in transparency and image quality.

- Competitive pricing compared to rivals.

- **Cons:**

- Early models had **noticeable camera visibility**.
- **Lower brightness** in the UDC zone.
- **Selfie quality lags behind punch-hole cameras** in dynamic lighting.

2. Xiaomi: The High-End Contender

Models: Xiaomi Mi 11 Ultra (Concept), Xiaomi MIX 4, Xiaomi 14 Ultra

Xiaomi has been a strong proponent of UDC technology, integrating it into its premium **MIX series** and showcasing concept devices with advanced implementations.

Technical Implementation

- **Mi 11 Ultra (Concept, 2021):**
- **MicroLED display** with **ultra-high transparency (90%+)**.
- **20MP front camera** with **AI super-resolution**.

- **No commercial release**, but demonstrated potential.

- **Xiaomi MIX 4 (2021):**

- **First mass-produced Xiaomi phone with UDC**.
- **400 PPI in the UDC zone** (vs. 450 PPI in the rest of the display).
- **20MP front camera** with **CUP (Camera Under Panel) 2.0 technology**.

- **Smaller camera area (3.8mm)** with **reduced diffraction**.

- **Xiaomi 14 Ultra (2024):**

- **Second-generation UDC with improved algorithms**.
- **Higher light transmission (45% vs. 35% in MIX 4)**.
- **32MP front camera** with **better HDR and low-light performance**.

Performance & Trade-offs

- **Pros:**
- **Superior build quality and premium design**.
- **Better image processing** than ZTEâ??s early models.

- **Faster adoption of new UDC iterations**.

- **Cons:**

- **MIX 4â??s UDC zone was still slightly visible**.
- **Higher price point** compared to competitors.
- **Selfie quality not on par with traditional front cameras**.

3. Samsung: The Display Giantâ??s Approach

Models: Samsung Galaxy Z Fold 3, Galaxy Z Fold 4, Galaxy Z Fold 5

Samsung, a leader in display technology, has taken a **cautious yet innovative** approach to UDC, primarily integrating it into its **foldable devices** rather than flagship slates.

Technical Implementation

- **Galaxy Z Fold 3 (2021):**
- **First Samsung device with UDC**.
- **4MP front camera** (lower resolution due to UDC limitations).
- **Lower PPI in the UDC zone (199 PPI vs. 426 PPI in the main display)**.

- **Visible camera area when the screen is off**.

- **Galaxy Z Fold 4 (2022):**

- **Improved transparency with a new pixel structure**.
- **Same 4MP camera but better software processing**.

- **Reduced visibility of the camera zone**.

- **Galaxy Z Fold 5 (2023):**

- **Further refinements in light transmission**.
- **Still 4MP, but enhanced AI processing**.
- **Near-invisible camera when the display is active**.

Performance & Trade-offs

- **Pros:**
- **Best-in-class display technology** (Dynamic AMOLED 2X).
- **Seamless integration in foldables** (no external camera bump).

- **Consistent improvements in transparency**.

- **Cons:**

- **Lower resolution front camera (4MP)**.
- **Selfie quality inferior to traditional punch-hole cameras**.
- **Limited to foldable devices (not in Galaxy S series yet)**.

4. OPPO: The Balanced Performer

Models: OPPO Find X3 Pro (Concept), OPPO Under-Screen Camera Phone (2023)

OPPO has been experimenting with UDC technology for years, showcasing prototypes before integrating them into commercial devices.

Technical Implementation

- **Find X3 Pro (Concept, 2021):**
- **Transparent OLED with 90%+ light transmission**.
- **32MP front camera** with **AI enhancement**.

- **No commercial release**, but demonstrated potential.

- **OPPO Under-Screen Camera Phone (2023):**

- **First OPPO phone with UDC in the mainstream market**.
- **400 PPI in the UDC zone**.
- **32MP front camera** with **improved low-light performance**.
- **Smaller camera area (3.5mm)**.

Performance & Trade-offs

- **Pros:**
- **Strong focus on display-camera balance**.
- **Better selfie quality than early ZTE models**.

- **Competitive pricing**.

- **Cons:**

- **Slower commercial adoption** compared to Xiaomi and ZTE.
- **Still visible camera zone under certain lighting**.

5. Vivo: The AI-Driven Approach

Models: Vivo APEX 2020 (Concept), Vivo X80 Pro (Partial UDC)

Vivo has taken a **hybrid approach**, combining UDC with AI-driven image processing to mitigate quality loss.

Technical Implementation

- **APEX 2020 (Concept):**
- **Full-screen UDC with no visible camera zone**.
- **32MP front camera** with **AI super-resolution**.
- **No mass production**.
- **Vivo X80 Pro (2022):**
- **Partial UDC (smaller camera area)**.
- **32MP front camera** with **Zeiss optics**.
- **AI-based image enhancement**.

Performance & Trade-offs

- **Pros:**
- **Strong AI processing for better selfies**.
- **Premium build quality**.
- **Hybrid approach reduces UDC drawbacks**.
- **Cons:**
- **Not a full UDC implementation**.
- **Higher cost than competitors**.

Key Challenges in Under-Display Camera Technology

Despite advancements, UDC technology still faces several hurdles:

1. **Light Transmission & Clarity**
2. The display layer **blocks a significant portion of light**, reducing camera performance.
3. **Diffraction and scattering** cause blurriness and reduced sharpness.
4. **Visible Camera Zone**
5. Early models had a **noticeable camera area** when the screen was off.

6. Newer iterations have reduced visibility but are **not entirely invisible**.

7. **Image Quality Trade-offs**

8. **Lower dynamic range** compared to traditional front cameras.
9. **Poor low-light performance** due to reduced light intake.

10. **AI reliance** can lead to **over-processing and unnatural images**.

11. **Durability & Longevity**

12. **Display degradation** over time may affect transparency.

13. **Higher risk of screen damage** due to the modified pixel structure.

14. **Cost & Manufacturing Complexity**

15. **Specialized display panels** increase production costs.
16. **Lower yields** due to precision requirements.

Future of Under-Display Camera Technology

The next generation of UDC technology is expected to address current limitations through:

- **MicroLED Displays** â?? Higher transparency and better light transmission.
- **Perovskite Materials** â?? Improved conductivity and light absorption.
- **AI & Computational Photography** â?? Enhanced image reconstruction.
- **Smaller, More Efficient Sensors** â?? Better performance in low light.
- **Hybrid Solutions** â?? Combining UDC with **periscope or under-display flash**.

Brands like **Samsung, Apple, and Google** are rumored to be working on **next-gen UDC**, potentially integrating it into flagship devices by **2025-2026**.

Conclusion

Under-display camera technology has made **significant strides** since its debut, with brands like **ZTE, Xiaomi, Samsung, OPPO, and Vivo** leading innovation. While early implementations suffered from **visible camera zones and poor image quality**, recent advancements have **dramatically improved transparency and performance**.

However, **trade-offs remain**, particularly in **selfie quality, low-light performance, and cost**. For now, UDC is most viable in **foldable devices and premium smartphones**, where design takes precedence

over camera performance.

As **display technology and AI processing** continue to evolve, under-display cameras may eventually **rival traditional front cameras**, offering a **truly bezel-less experience** without compromising functionality. Until then, consumers must weigh the **aesthetic benefits against the practical limitations** when choosing a UDC-equipped device.

Category

1. Uncategorized

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