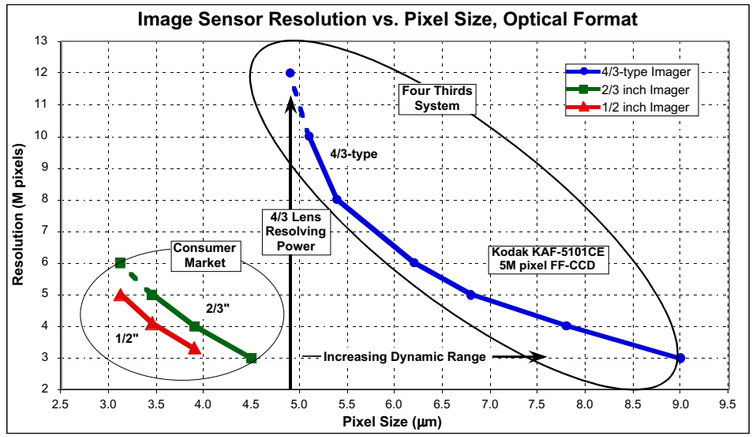

Figure 6: Image sensor resolution vs. pixel size for various optical formats

ding charge capacity, the Four Thirds System cameras achieve 11 to 12 bits of dynamic range, equivalent to the best digital SLR cameras in the professional market today.

Photo-Sensitivity

Many of today's digital cameras are deficient in photo-sensitivity (effective ISO), performing relatively poorly when capturing action photography in poorly illuminated environments. To achieve a higher effective ISO, the digital gain in these cameras is often increased and, with this, a commensurate level of noise is introduced into the images. Many amateur photographers have been disappointed with the performance of their consumer digital cameras in dimly lit gymnasiums, auditoriums or other venues where lighting is insufficient or where motion is involved such as in sporting events. However, with a Four Thirds System digital camera, the effective ISO range is now 100 to 800 and can produce quality images in this difficult photographic space. It's fundamental physics: a larger imaging area, combined with larger pixels and new lenses specifically designed for silicon sensors, results in improved image quality expected in professional digital SLR cameras.

Signal to Noise Ratio

A classical measure of image quality in digital photography is the signal-to-noise ratio of the image sensor and camera system. This factor can be defined as the ratio of the signal from the sensor for a given illumination condition and exposure time relative to the measured noise produced from the sensor's dark current and read-out circuitry. While many photographers seem satisfied with the image quality of today's digital cameras, Kodak's 4/3-type image sensor , based on advanced full-frame CCD technology, delivers noticeably better images and establishes a higher standard for digital pictorial quality for professional photographers.

Kodak KAF-5101CE – A 5 Mega-pixel, 4/3-type Image Sensor

The Kodak KAF-5101CE is a full-frame color CCD (charge-coupled-device) that has been specifically designed for Four Thirds System digital SLR cameras. The KAF-5101CE incorporates 6.8-µm pixels with an integral pigment color filter array and micro-lenses for superb color rendition and high photo-sensitivity. It delivers high image quality with low noise at frame rates of up to four (4) frames per second and an ISO range from ISO 100 to ISO 800. The KAF-5101CE is available with a companion timing generator chip that is specifically designed to optimize its performance for digital still cameras. Together, these chips augment Kodak's broad line of image sensor solutions for performance imaging applications.

The Bottom Line

Digital from the ground up, the Four Thirds System creates a new category of digital still cameras with its combination of professional quality and versatility at affordable prices. Kodak offers a 5 mega-pixel 4/3-type image sensor solution that lies at the heart of this exciting new digital SLR camera format for professionals and advanced amateurs.

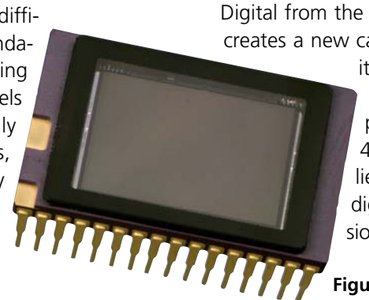

Figure 7: Kodak KAF-5101CE, 5 Mega-pixel Full-Frame Color CCD Image Sensor

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4/3-type Image Sensors in Digital Still Camera Applications

Silicon Image Sensors - In the Digital Still Camera Marketplace

Silicon image sensors have been paramount in establishing the wide market acceptance of digital still photography. Kodak's Image Sensor Solutions division offers a broad array of image sensors (see **Fig. 1**) for a variety of digital imaging applications. Now a next-generation format is being introduced that will dramatically alter the market landscape. Referred to as the "4/3-type" format, this 4:3 aspect ratio format with a 22-mm photographic diagonal is targeted for the professional digital camera market segment. It will enable a revolutionary new generation of high-quality, highly portable digital still cameras for professional and advanced amateur photographers.

Figure 1: Kodak's image sensors for performance imaging applications.

Digital from the ground up, the Four Thirds System unburdens camera makers from compatibility with the traditional camera and lens formats from film-based imaging, allowing them to optimize all the elements of digital camera design to achieve excellent quality and high functionality with a more compact camera system. The power of the 4/3-type imager comes from the synergies of its optimally matched Four Thirds System cameras and lenses. Relative to today's consumer cameras, the sensors are large, high resolution devices with excellent dynamic range, photo-sensitivity and signal-to-noise performance. And, relative to the professional 35-mm format cameras, the new Four Thirds System digital SLR (single lens reflex) cameras offer a set of interchangeable lenses that will be inherently lighter weight, more compact and highly portable while providing professional quality images.

The new 4/3-type image sensor offers professional image quality with a smaller optical format, creating an exciting advantage for professional and advanced amateur photographers. This new category of digital SLR cameras will appeal to those seeking higher performance and versatility , as well as improved value relative to traditional 35-mm digital SLR cameras and lenses.

Common Optical Formats

Digital still camera formats vary widely across the different market segments. At the high end of the professional market segment, for example, digital cameras based on so-called '645' medium format focal plane use image sensors that are larger than the 35-mm optical format (See **Fig. 2**); while 35-mm and APS format imager sensors serve the professional and advanced amateur markets, which utilize 35-mm digital SLR cameras. Consumer point and shoot cameras, in contrast, use much smaller silicon sensors such as 2/3 inch, 1/2 inch, 1/3 inch format and even smaller. Camera makers must choose an imager format based on the price target for their camera, since the imager cost increases with its size. While the precise geometries vary from chip maker to chip maker, the most common formats are categorized in the table on the following page. The 4/3-type image sensor, with new lenses designed to match the optical format, provides photographers with the digital still camera performance expected by professionals and advanced amateurs.

Imager Format	Aspect Ratio	Width H (mm)	Height V (mm)	Diagonal (mm)
1/4"	4:3	3.2	2.4	4
1/3"	4:3	4.8	3.6	6
1/2"	4:3	6.4	4.8	8
2/3"	4:3	8.8	6.6	11
1"	4:3	12.8	9.6	16
4/3-type[1]	4:3	17.8	13.4	22.3
APS [2]	3:2	25.1	16.7	30.1
35 mm	3:2	36.0	24.0	43.3
36x36	1:1	36.0	36.0	51.9
645	4:3	56.0	41.5	69.7

Footnotes:
1. 4/3-type imager as described by Kodak KAF-5101CE image sensor
2. Common 'APS' digital format: 23.7 mm (H) x 15.6 mm (V), 28.4 mm diagonal

The 4/3-type Optical Format

The new 4/3-type format defines an optimal sensor size for its target market, Four Thirds System digital SLR cameras for the professional segment. It's more compact than the APS format, yet has four times the active area of the 2/3 inch format, effectively quadrupling the photographic area available for capturing an image over the best sensors available in the consumer market segment today (See **Fig. 3** for relative sizes). Moreover, the characteristics of 4/3-type image sensors have been designed to work optimally with Four Thirds System lenses, and these new lenses are specifically being designed to operate with silicon sensors, not with traditional silver halide film.

Wide Angle Photography with Digital SLR Cameras

In commercially available 35-mm SLR digital cameras today, the image sensor selected for the camera is often considerably smaller in area than the size of the 35-mm film for which the lens was originally designed. This trade-off is necessary in order to save cost, but it also causes some serious compromises in performance. The size difference, for example, introduces an undesirable focal length magnification error, which effectively reduces the photographic field of view for a given focal length (See **Fig. 4**). This creates a barrier to achieving wide angle photography with short focal length lenses that are designed for a full 35-mm format frame.

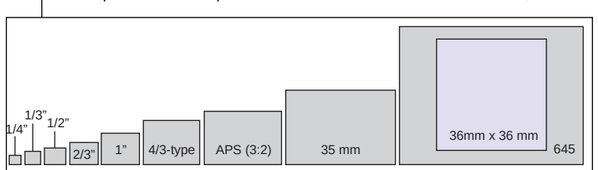

Figure 2: Common image sensor formats used in digital still cameras

While full 35-mm format image sensors can be used to alleviate this problem, their higher cost results in a camera price that may be prohibitive for advanced amateurs and even many professionals. Since 4/3-type image sensors and lenses are precisely matched, there's no magnification error introduced. As such, no matter what type of lens is being used--wide angle, variable zoom or telephoto--the full field of view presented to the user is usable photographic area. This provides professional and advanced amateur photographers with wide angle photographic capability that is only commercially available in more expensive camera systems.

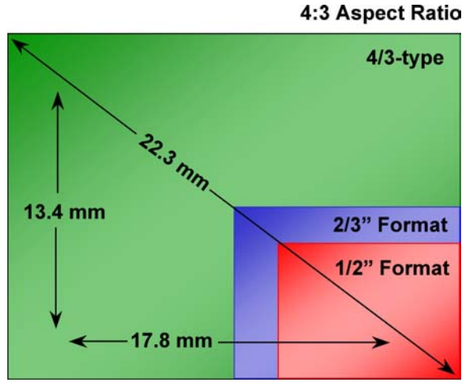

Figure 3: Comparison of 4/3-type, 2/3 inch and 1/2 inch optical formats

Matching Image Sensor and Lenses In Digital Camera Design

The 4/3-type image sensor and Four Thirds System lenses have been co-optimized without the constraints of traditional 35-mm film lenses. Based on an understanding of how silicon sensors operate, these new lenses are more tele-centric, introducing light rays to the image sensor surface at incident angles that are more perpendicular. This reduces the effect of peripheral fading observed with traditional 35-mm film lenses used in digital SLRs today, where sensitivity roll-off near the edges is considerable due to large incident angles (see **Fig. 5**).

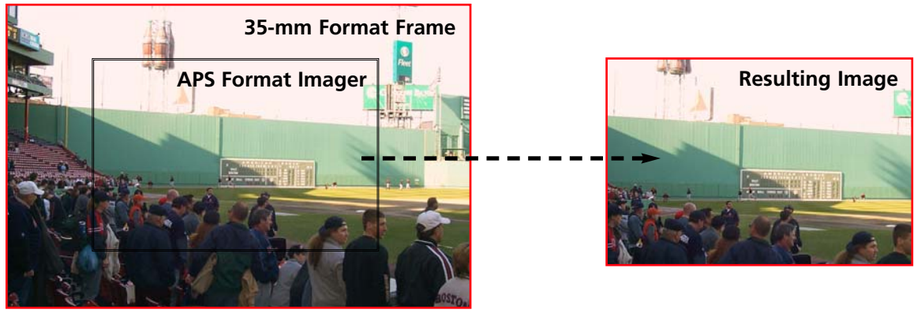

Figure 4: Photographic effect of an APS format imager used with 35-mm format camera with an f/3.0, 38-mm effective focal length lens

The problem is confounded because the incident angle is a strong function of the focal length and f-stop of traditional 35-mm lenses and, as such, peripheral fading is dependent on each lens being used. While large incident angles are not a problem for film-based photography (because silver-halide photo-sensitivity is relatively independent of incident light angle), it is highly desirable that the incident angles be more normal (perpendicular) for silicon image sensors, whose semiconductor architectures prefer normal incidence.

Resolution and Pixel Size

Despite the on-going "pixel wars" among some digital camera makers in the consumer market, packing more and more pixels into the same size 1/2 inch format or 2/3 inch format sensor ultimately leads to diminishing returns. As one adds pixels, the constraint of the optical format limits the pixel size, reducing the photo-sensitive area and charge capacity of these shrinking pixels.

The 4/3-type image sensor alleviates this conflict by defining an active area four times larger than 2/3 inch sensors, which dramatically improves effective ISO, dynamic range and signal-to-noise performance. It is a high resolution format from the first generation on, with significant "head room" for going to much higher pixel counts and well beyond the practical limitations of smaller format sensors. Kodak's first 4/3-type image sensor, the KAF-5101CE, has 5-million 6.8 µm x 6.8 µm pixels and renders exceptional detail while maintaining high image quality; and 8 million, 10 million or even 12 million pixels are not unrealistic in the years to come for the 4/3-type format (see **Fig. 6**).

Dynamic Range

Also referred to as "bit depth" or "contrast range," the dynamic range of an image sensor can be thought of in terms of a camera's ability to render the gradation of shades of gray in the highlights and shadows of a scene. The effective dynamic range can be examined in the details of the brightest highlights in an image and in the darkest shadows of an image. Some of the today's best studio-grade camera systems claim 14 bits of dynamic range (some scanning backs even claim 16 bits) while most of today's consumer cameras deliver 8 to 10 bits. Due to the larger pixel size and correspon-

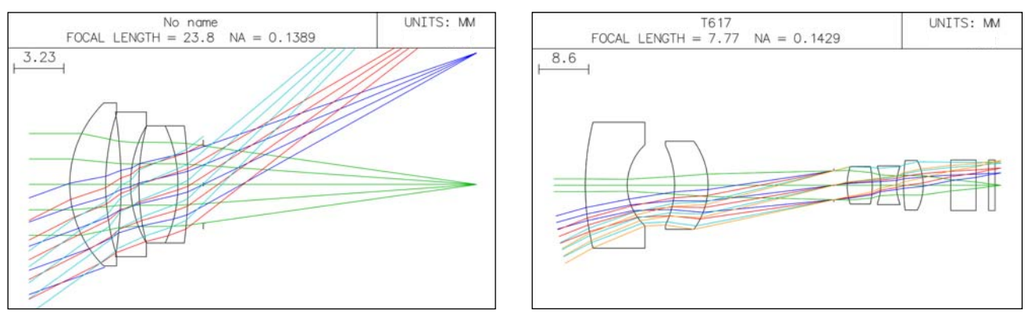

Figure 5: Incident light rays for a non-telecentric film camera objective compared to a nearly telecentric digital camera objective. Since telecentric designs typically require more elements the smaller Four Thirds System lens elements result in more compact, cost effective lenses as compared to similar designs in the 35-mm format.