ding charge capacity, the Four Thirds System cam-
eras achieve 11 to 12 bits of dynamic range, equiv-
alent to the best digital SLR cameras in the profes-
sional market today.

Photo-Sensitivity
Many of today's digital cameras are deficient inphoto-sensitivity (effective ISO), performing relative-
ly poorly when capturing action photography in poorly illuminated environments. To achieve a high-
er 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 stairwells, gyms, 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 diffi-
cult 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 pho-
tography 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 relative to
the measured noise pro-
duced from the sensor's dark
and read-out circuit-
ry. While many photogra-
phers seem satisfied with the
image quality of today's dig-
tital cameras, Kodak's 4/3-
type image sensor, based on
advanced full-frame CCD
technology, delivers notice-
ably better images and estab-
lishes 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-color pixel (charge-coupled-device) that has been specifically
designed for Four Thirds System digital SLR cameras. The KAF-5101CE incorporates 8.6-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 perform-
ance for digital still cameras. Together, these chips augment Kodak's broad line of image sensor solu-
tions 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 qual-
ity 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 profes-
sionals and advanced amateurs.

Silicon Image Sensors - In the Digital Still Camera Marketplace
Si-
licon image sensors have been paramount
in establishing the wide market acceptance
developing 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 photo-
graphic diagonal is targeted for the profes-
sional digital camera market segment. It will
enable a revolutionary new generation of
high-quality, highly portable digital still cam-
eras for professional and advanced amateur
photographers.

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 excel-
lent quality and high functionality with a more com-
 pact camera system. The power of the 4/3-type
image sensor 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,
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 cate-
gory of digital SLR cameras will appeal to those
seeking higher performance and versatility, as well
as improved value relative to traditional 35-mm dig-
ital SLR cameras and lenses.
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 a more serious (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 a sensor is limited by both the optical format and pixel size. Increasing the pixel count, 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.

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 used—wide-angle, variable zoom or telephoto—the full field of view presented to the user is usable photographically. This provides professional and advanced amateur photographers with wide angle photographic capability that is only commercially available in more expensive camera systems.

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 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.

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 used—wide-angle, variable zoom or telephoto—the full field of view presented to the user is usable photographically. This provides professional and advanced amateur photographers with wide angle photographic capability that is only commercially available in more expensive camera systems.

ISO, Dynamic Range and Signal-to-Noise Performance

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 5.6 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 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 correspondingly larger active area, 4/3-type cameras are able to render dynamic range in excess of 14 bits, with the best current models delivering 16 bits of dynamic range (16-bit A/D, or “bit depth”).

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

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

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.

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.