

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

IMMERVISION, INC.

Plaintiff,

v.

APPLE INC.,

Defendant.

Case Number: 1:21-cv-1484-MN-CJB

IMMERVISION, INC.

Plaintiff,

v.

APPLE INC.,

Defendant.

Case Number: 1:21-cv-1570-MN-CJB

IMMERVISION, INC.

Plaintiff,

v.

APPLE INC.,

Defendant.

Case Number: 1:21-cv-01733-MN-CJB

PLAINTIFF'S INITIAL INFRINGEMENT CONTENTIONS

Plaintiff ImmerVision, Inc. ("ImmerVision") hereby submits these Initial Infringement Contentions and claim chart(s).

The patents in suit are U.S. Patent No. 6,844,990 ("the '990 Patent") and 10,795,120 ("the '120 Patent") (together, the "Asserted Patents").

ImmerVision submits that the pertinent field of art for the Asserted Patents is optical lens design, and that one of ordinary skill in the art will have at least a master's degree in optics or a related discipline and at least three years work experience in optical design.

'990 Patent, Claim 21

Claim 21 of the '990 Patent is asserted in this litigation against the iPhone 13 Pro and 13 Pro Max. Infringement by the iPhone 13 Pro is shown in the attached Exhibit A. Based upon publicly available information including Apple's advertisements, the iPhone 13 Pro Max contains the same ultra wide lens and camera as the iPhone 13 Pro, and therefore infringes claim 21 of the '990 Patent in the same manner as shown in Exhibit A.

The analysis shown in Exhibit A was undertaken according to the following procedure. The relevant objective lens of each phone was analyzed by opening the phone, removing the lens from the relevant camera module, and measuring the distortion using an Optikos LensCheck VIS machine. The Optikos outputs an Excel file showing the distortion profile of the lens as shown in the position graph in Exhibit A. The resolution graph in Exhibit A was then calculated using mathematical operations in Excel. After analysis by the Optikos, the lens was cut by placing it on a glass slide, covering the lens using 2-ton epoxy manufactured by Devcon, and allowing the epoxy to dry for 24 hours. The lens was cut using a Disco DAD3350 dicing saw using a 90 mm diameter, 0.4 mm thick saw blade, in the multi-pass operating mode at $400\mu\text{m} \leq \text{Z-Cut} \leq 700\mu\text{m}$.

'990 Patent, Claim 27

Claims 27, 2, and 4 of the '990 Patent are asserted against the iPhone 12, 12 Mini, 12 Pro, 12 Pro Max, 13, and 13 Mini smartphones and the iPad Pro 2021 tablet¹, and claims 29 and 30 are asserted against the iPhone 12, 12 Mini, 12 Pro, 12 Pro Max smartphones and the iPad Pro 2021 tablet. Exemplary claim charts showing infringement are attached as follows:

- Exhibit B: iPhone 12 Pro;

¹ Based on Apple's marketing materials, ImmerVision believes both available sizes of the iPad Pro 2021 include the same wide-angle, rear-facing camera module and therefore both sizes are accused.

- Exhibit C: iPhone 13; and
- Exhibit D: iPad Pro 2021.

The analyses shown in Exhibits B-D were undertaken according to the following procedure. Each respective smartphone was mounted in the center of the distortion measurement test bench, as shown below:



The test bench consists of alternating black and white shapes within a cylinder. Each of the black rectangles surrounding the top of the cylinder, as well as the intervening white spaces, represents two degrees (2°) of the field of view as seen from the center of the test bench. The phone was aligned diagonally such that the black and white rectangles extend from one corner of the resulting image to the diagonally opposite corner. Images were then captured with the phone

using the resolution of the full sensor, both with the “Lens Correction” setting enabled and disabled. By counting the number of black rectangles and white spaces, the field of view of the digital image can be calculated, confirming that the image is panoramic. Data was then extracted from the image to analyze at which pixel the transition from black to white or white to black occurred. Using Microsoft Excel, the distortion present in the image can be calculated by comparing these black-to-white or white-to-black transition points to the pixels on which such transitions would occur on a distortion-free image. This distortion data extracted from the images captured by the phones is shown in the resolution graphs in the attached claim charts.

Each phone was also mounted on a tripod to photograph a chessboard, carefully aligning the device such that each corner is aligned on the same row and column of squares as each horizontally and vertically opposite corner. From images captured of the chess board, straight lines can be added in image processing software to determine whether the lines of the chessboard in the image are straight or curved.

The relevant objective lens of each device was analyzed by opening the device, removing the lens from the relevant camera module, and measuring the distortion using an Optikos LensCheck VIS machine. The Optikos outputs an Excel file showing the distortion profile of the lens as shown in the position graph in Exhibits B-D. The resolution graphs in Exhibits B-D were then calculated using mathematical operations in Excel. After analysis by the Optikos, the distortion measured in the lens was compared to the distortion measured in the image captured on the test bench.

Based upon publicly available information including Apple’s advertisements: the iPhone 12 Mini, 12, and 12 Pro Max contain the same ultra wide lens and camera as the iPhone 12 Pro, and therefore infringe claims 27, 2, 4, 29, and 30 of the ‘990 Patent in the same manner as shown

in Exhibit B; and the iPhone 13 Mini contains the same ultra wide lens and camera as the iPhone 13, and therefore infringe claims 27, 2, and 4 of the '990 Patent in the same manner as shown in Exhibit C.

Having had knowledge of the '990 Patent since at least October 22, 2021, Apple has induced infringement of claims 27, 2, 4, 29, and 30 of the '990 Patent by directing its customers and users of the accused devices to capture and display photographs using the ultra wide camera. As shown for example in the screen captures of Apple's website attached as Exhibit H to the Third Amended Complaint, Apple promotes the use of the "ultra wide camera" on each product as a selling feature of the accused devices. As shown in the attached claim charts, the ultra wide camera of the accused devices perform the infringing method each time a photo is taken and displayed, so long as the "lens correction" feature is enabled.

'120 Patent

Claims 1, 3, 5 and 7 of the '120 Patent are asserted against the Apple iPhone 11, 11 Pro, 11 Pro Max, 12, 12 Mini, 12 Pro, 12 Pro Max, 13, 13 Mini, 13 Pro, 13 Pro Max, 14, and 14 Plus smartphones and the iPad 2021 tablet,² and claim 4 is further asserted against the iPhone 13, 13 Mini, 14, and 14 Plus smartphones. Exemplary claim charts showing infringement are attached as follows:

- Exhibit E: iPhone 11 Pro;
- Exhibit F: iPhone 12 Pro;
- Exhibit G: iPhone 13 Mini;
- Exhibit H: iPhone 13 Pro;

² Based on Apple's marketing materials, ImmerVision believes both available sizes of the iPad Pro 2021 include the same wide-angle, rear-facing camera module and therefore both sizes are accused.

- Exhibit I: iPhone 14; and
- Exhibit J: iPad Pro 2021.

The analyses shown in Exhibits E-J were undertaken according to the following procedure. The relevant objective lens of each device was analyzed by opening the device, removing the lens from the relevant camera module, and measuring the distortion, MTF, chief ray angle (13 Mini and 14 only), image circle diameter, and field of view of the lens using an Optikos LensCheck VIS machine. The Optikos outputs one or more Excel files showing the distortion profile, MTF, and chief ray angle of the lens as shown in the position³ graph in Exhibits E-J. After analysis by the Optikos, the field of view of the lens was determined by viewing the data captured by the Optikos, the track length was measured by placing the camera module in a set of calipers capable of measuring to the hundredth of a millimeter, and the image circle diameter is calculated by viewing the maximum field of view angle reported by the Optikos and multiplying by two.

Based upon publicly available information including Apple's advertisements: the iPhone 11, and 11 Pro Max contain the same ultra wide lens and camera as the iPhone 11 Pro, and therefore infringe claims 1, 3, 5, and 7 of the '120 Patent in the same manner as shown in Exhibit E; the iPhone 12 Mini, 12, and 12 Pro Max contain the same ultra wide lens and camera as the iPhone 12 Pro, and therefore infringe claims 1, 3, 5, and 7 of the '120 Patent in the same manner as shown in Exhibit F; the iPhone 13 contains the same ultra wide lens and camera as the iPhone 13 Mini, and therefore infringe claims 1, 3-5, and 7 of the '120 Patent in the same manner as shown in Exhibit G; and the iPhone 13 Pro Max contains the same ultra wide lens and camera as

³ As with the '990 Patent, the resolution graph is generated in Excel using standard mathematical operators.

the iPhone 13 Pro, and therefore infringes claims 1, 3, 5, and 7 of the '120 Patent in the same manner as shown in Exhibit H; and the iPhone 14 Plus contains the same ultra wide lens and camera as the iPhone 14, and therefore infringes claims 1, 3-5, and 7 of the '120 Patent in the same manner as shown in Exhibit I.

Dated: November 1, 2022

Respectfully submitted,

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& NADEL LLP

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CERTIFICATE OF SERVICE

I hereby certify that, on November 1, 2022, I caused copies of the foregoing PLAINTIFF’S INITIAL INFRINGEMENT CONTENTIONS to be served on the following by electronic mail.

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/s/ Keith A. Jones
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US PATENT 10,795,120 v. APPLE IPHONE 11 PRO

<u>Claim</u>	<u>Apple iPhone 11 Pro Smartphone</u>
1. A miniature wide-angle optical apparatus comprising:	The iPhone 11 Pro has a wide-angle camera with a wide-angle lens including the features listed below.
a light-receiving first surface;	 First surface of the lenses The wide-angle lens has a first surface receiving light.
a focal plane;	In a digital camera, an image sensor is placed approximately at the focal plane of the objective lens in order to obtain a focused image. The wide-angle lens from the iPhone 11 Pro necessarily has a focal plane, as evidenced by the placement of an image sensor that obtains a clear, focused image.  Location of focal plane

<u>Claim</u>	<u>Apple iPhone 11 Pro Smartphone</u>
a total track length measured from a center of the first surface to the focal plane;	 A microscopic image showing a rectangular sensor track on a substrate. A scale bar above the track indicates a length of 6.0mm. The distance from the first surface to the image sensor was measured at a maximum of 6.0 mm. Because the image sensor sits approximately at the focal plane, the total track length is measured from the first surface to the image sensor and therefore is at most 6.0 mm.
a miniaturization ratio with a value less than 3.0, the miniaturization ratio being a ratio of the total track length divided by an image circle diameter; and	The total track length, as measured above, is at most 6.0 mm. The image circle diameter was measured via the Optikos LensCheck measurement machine and found to be 5.29mm with a field of view of 130°. Therefore, the miniaturization ratio is at most 1.134 (6.0/5.29).

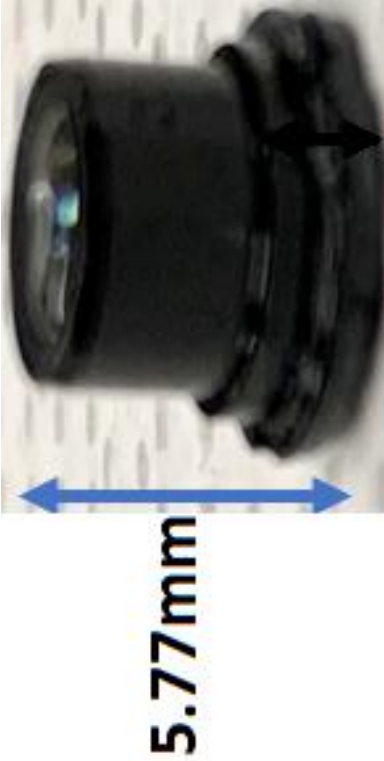
Claim	Apple iPhone 11 Pro Smartphone																											
a non-linear targeted resolution to intentionally create a zone in an image captured by the miniature wide-angle optical apparatus with a lower or higher object to image magnification compared to linear targeted resolution,	<table><caption>Approximate data points from the graph</caption><thead><tr><th>Half field of view angle (degree)</th><th>Resolution (µm/degree) - iPhone 11 Pro</th><th>Resolution (µm/degree) - Linear resolution</th></tr></thead><tbody><tr><td>0</td><td>28</td><td>40</td></tr><tr><td>10</td><td>29</td><td>40</td></tr><tr><td>20</td><td>30</td><td>40</td></tr><tr><td>30</td><td>40</td><td>40</td></tr><tr><td>40</td><td>45</td><td>40</td></tr><tr><td>50</td><td>52</td><td>40</td></tr><tr><td>60</td><td>55</td><td>40</td></tr><tr><td>70</td><td>52</td><td>40</td></tr></tbody></table> The resolution of the wide-angle lens from the iPhone 11 Pro was measured with the Optikos LensCheck measurement machine. As seen in the graph created by the data captured by the Optikos, the resolution is non-linear and is targeted to maximize magnification within approximately 20° of the edge of the field of view. This non-linear targeted resolution creates a zone in the image with lower object-to-image magnification and a zone with higher object-to-image magnification compared to the linear resolution.	Half field of view angle (degree)	Resolution (µm/degree) - iPhone 11 Pro	Resolution (µm/degree) - Linear resolution	0	28	40	10	29	40	20	30	40	30	40	40	40	45	40	50	52	40	60	55	40	70	52	40
Half field of view angle (degree)	Resolution (µm/degree) - iPhone 11 Pro	Resolution (µm/degree) - Linear resolution																										
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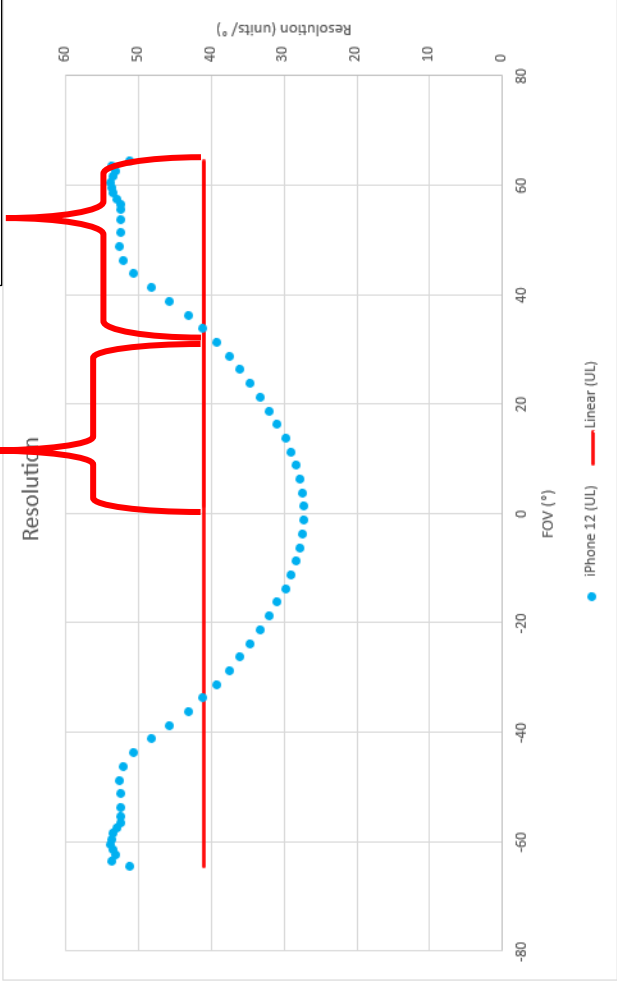
Claim	Apple iPhone 11 Pro Smartphone																										
the lower or higher object to image magnification being used to compensate, at least in part, for a lower image quality due to at least one of a drop of relative illumination or a drop of MTF in a zone of the image,	<table border="1"> <caption>Data points estimated from the MTF graph</caption> <thead> <tr> <th>Half field of view angle (degree)</th> <th>MTF (%)</th> </tr> </thead> <tbody> <tr><td>0</td><td>90</td></tr> <tr><td>10</td><td>65</td></tr> <tr><td>20</td><td>68</td></tr> <tr><td>30</td><td>65</td></tr> <tr><td>33</td><td>60</td></tr> <tr><td>40</td><td>50</td></tr> <tr><td>45</td><td>45</td></tr> <tr><td>50</td><td>35</td></tr> <tr><td>55</td><td>30</td></tr> <tr><td>60</td><td>25</td></tr> <tr><td>65</td><td>20</td></tr> <tr><td>70</td><td>25</td></tr> </tbody> </table> The image quality, as demonstrated by the MTF measurements shown above, in the zone having a higher object-to-image magnification (greater than about 33 degrees from center) is lower than in the center zone of the image, where there is a lower object to image magnification. This graph shows data captured by the Optikos Lenscheck measurement machine. Specifically, the graph shows the average of the Sagittal and Tangential MTFs measured at 100 lp/mm. The MTF is seen to drop sharply after about 30 degrees from center to a minimum at the edge of the field of view, which mainly coincides with the highest resolution areas of the lens. The non-linear targeted resolution therefore compensates, at least in part, for the lower image quality in this zone of the image. Based on data measured on the Optikos measurement machine, the total field of view of the lens is about 130°. See, e.g., the graphs of resolution and MTF above, which show half-field view angles reaching approximately 65°. Further, based on Apple’s own product literature, the “ultra wide” camera has a field of view of at least 120°. See https://www.apple.com/shop/product/FWCU2LL/A/refurbished-iphone-11-pro-512gb-gold-unlocked.	Half field of view angle (degree)	MTF (%)	0	90	10	65	20	68	30	65	33	60	40	50	45	45	50	35	55	30	60	25	65	20	70	25
Half field of view angle (degree)	MTF (%)																										
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an opening angle of light entering the optical apparatus being over 100°.																											

<u>Claim</u>	<u>Apple iPhone 11 Pro Smartphone</u>
3. The miniature wide-angle optical apparatus of claim 1, wherein a targeted resolution curve has a change of direction near an edge of a field of view.	The graph plots Resolution (µm/degree) on the y-axis (0 to 60) against Half field of view angle (degree) on the x-axis (0 to 70). A blue curve represents the iPhone 11 Pro's resolution, which is non-linear. It starts at approximately 25 µm/degree at 0 degrees, rises to a peak of about 45 µm/degree at 45 degrees, and then drops sharply to about 25 µm/degree at 65 degrees. A red horizontal line represents linear resolution at approximately 40 µm/degree. A red circle highlights the peak at 45 degrees, with an arrow pointing to it labeled 'Change of direction'. The text 'Higher magnification' is written vertically in orange on the left, and 'Lower magnification' is written vertically in orange on the right. As can be seen in the graph of the non-linear resolution, the targeted resolution of the iPhone 11 generally increases from the center to a half-field angle of about 45°, remains constant from about 45° to about 63°, then abruptly and significantly drops just near the edge of the field of view around 65°.

<u>Claim</u>	<u>Apple iPhone 11 Pro Smartphone</u>
5. The miniature wide-angle optical apparatus of claim 1, further comprising a plurality of optical elements, at least one of the plurality of optical elements defining the first surface.	Apple's website lists the wide-angle optical apparatus of the iPhone 14 as having a "five-element lens." See https://support.apple.com/kb/SP804?locale=en_US. When the camera module is removed from the phone and the protective glass cover is removed from the lens, one can see that the outermost lens element is the light receiving first surface. 
7. The miniature wide-angle optical apparatus of claim 1, wherein the miniaturization ratio value is less than 2.0.	As noted above, the miniaturization ratio was calculated to be at most 1.134, which is less than 2.0.

<u>Claim</u>	<u>Apple iPhone 12 Pro Smartphone</u>
1. A miniature wide-angle optical apparatus comprising:	The iPhone 12 Pro has a wide-angle camera with a wide-angle lens including the features listed below.
a light-receiving first surface;	 5.77mm First surface of the lens The wide-angle lens has a first surface receiving light.

<u>Claim</u>	<u>Apple iPhone 12 Pro Smartphone</u>
a focal plane;	In a digital camera, an image sensor is placed approximately at the focal plane of the objective lens in order to obtain a focused image. The wide-angle lens from the iPhone 12 Pro necessarily has a focal plane, as evidenced by the placement of an image sensor that obtains a clear, focused image.  Photograph of iPhone 12 Pro ultra wide angle lens.
a total track length measured from a center of the first surface to the focal plane;	 The distance from the first surface to the image sensor was measured at a maximum of 5.77 mm. Because the image sensor sits approximately at the focal plane, the total track length is measured from the first surface to the image sensor and therefore is at most 5.77 mm.

Claim	Apple iPhone 12 Pro Smartphone
a miniaturization ratio with a value less than 3.0, the miniaturization ratio being a ratio of the total track length divided by an image circle diameter; and a non-linear targeted resolution to intentionally create a zone in an image captured by the miniature wide-angle optical apparatus with a lower or higher object to image magnification compared to linear targeted resolution,	The total track length, as measured above, is at most 5.77 mm. The image circle diameter was measured via the Optikos LensCheck measurement machine and found to be 5.33mm with a field of view of 130°. Therefore, the miniaturization ratio is at most 1.08 (5.77/5.33).
a non-linear targeted resolution to intentionally create a zone in an image captured by the miniature wide-angle optical apparatus with a lower or higher object to image magnification compared to linear targeted resolution,	Lower Object-to-Image Magnification Zone Higher Object-to-Image Magnification Zone  The resolution of the wide-angle lens from the iPhone 12 Pro was measured with the Optikos LensCheck measurement machine. As seen in the graph created by the data captured by the Optikos, the resolution is non-linear and is targeted to maximize magnification within approximately 25° of the edge of the field of view. This non-linear targeted resolution creates a zone in the image with lower object-to-image magnification and a zone with higher object-to-image magnification compared to the linear resolution.

Claim	Apple iPhone 12 Pro Smartphone																																
the lower or higher object to image magnification being used to compensate, at least in part, for a lower image quality due to at least one of a drop of relative illumination or a drop of MTF in a zone of the image,	<table border="1"> <caption>Data points estimated from the graph</caption> <thead> <tr> <th>Half field of view angle (degree)</th> <th>MTF (%)</th> </tr> </thead> <tbody> <tr><td>0</td><td>95</td></tr> <tr><td>5</td><td>92</td></tr> <tr><td>10</td><td>88</td></tr> <tr><td>15</td><td>85</td></tr> <tr><td>20</td><td>82</td></tr> <tr><td>25</td><td>78</td></tr> <tr><td>30</td><td>72</td></tr> <tr><td>35</td><td>65</td></tr> <tr><td>40</td><td>58</td></tr> <tr><td>45</td><td>52</td></tr> <tr><td>50</td><td>48</td></tr> <tr><td>55</td><td>45</td></tr> <tr><td>60</td><td>42</td></tr> <tr><td>65</td><td>38</td></tr> <tr><td>70</td><td>35</td></tr> </tbody> </table> The image quality, as demonstrated by the MTF measurements shown above, in the zone having a higher object-to-image magnification (greater than about 35 degrees from center) is lower than in the center zone of the image, where there is a lower object to image magnification. This graph shows data captured by the Optikos Lenscheck measurement machine. Specifically, the graph shows the average of the Sagittal and Tangential MTFs measured at 100 lp/mm. The MTF is seen to drop sharply after about 30 degrees from center to a minimum at the edge of the field of view, which mainly coincides with the highest resolution areas of the lens. The non-linear targeted resolution therefore compensates, at least in part, for the lower image quality in this zone of the image. Based on data measured on the Optikos measurement machine, the total field of view of the lens is almost 130°. See, e.g., the graphs of resolution and MTF above, which show half-field view angles reaching nearly 65°. Further, based on Apple’s own product literature, the “ultra wide” camera has a field of view of at least 120°. See https://support.apple.com/kb/SP831?locale=en_US.	Half field of view angle (degree)	MTF (%)	0	95	5	92	10	88	15	85	20	82	25	78	30	72	35	65	40	58	45	52	50	48	55	45	60	42	65	38	70	35
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Claim	Apple iPhone 12 Pro Smartphone
3. The miniature wide-angle optical apparatus of claim 1, wherein a targeted resolution curve has a change of direction near an edge of a field of view.	As can be seen in the graph of the non-linear resolution, the targeted resolution of the iPhone 12 Pro generally increases from the center to a half-field angle of about 45°, remains generally constant from about 45° to about 62°, then abruptly and significantly decreases just near the edge of the field of view around 63°. Apple's website lists the wide-angle optical apparatus of the iPhone 12 Pro as having a "five-element lens." See https://support.apple.com/kb/SP831?locale=en_US. When the camera module is removed from the phone and the protective glass cover is removed from the lens, one can see that the outermost lens element is the light receiving first surface.
5. The miniature wide-angle optical apparatus of claim 1, further comprising a plurality of optical elements, at least one of the plurality of optical elements defining the first surface.	As noted above, the miniaturization ratio was calculated to be at most 1.08, which is less than 2.0.
7. The miniature wide-angle optical apparatus of claim 1, wherein the miniaturization ratio value is less than 2.0.	

<u>Claim</u>	<u>Apple iPhone 13 Mini Smartphone</u>
1. A miniature wide-angle optical apparatus comprising:	The iPhone 13 Mini has a wide-angle camera with a wide-angle lens including the features listed below.
a light-receiving first surface;	 6.31mm First surface of the lens The wide-angle lens has a first surface receiving light.
a focal plane;	 6.31mm Location of focal plane In a digital camera, an image sensor is placed approximately at the focal plane of the objective lens in order to obtain a focused image. The wide-angle lens from the iPhone 13 Mini necessarily has a focal plane, as evidenced by the placement of an image sensor that obtains a clear, focused image.

<u>Claim</u>	<u>Apple iPhone 13 Mini Smartphone</u>
a total track length measured from a center of the first surface to the focal plane;	The distance from the first surface to the image sensor was measured at a maximum of 6.31 mm. Because the image sensor sits approximately at the focal plane, the total track length is measured from the first surface to the image sensor and therefore is at most 6.31 mm.
a miniaturization ratio with a value less than 3.0, the miniaturization ratio being a ratio of the total track length divided by an image circle diameter; and	The total track length, as measured above, is at most 6.31 mm. The image circle diameter was measured via the Optikos LensCheck measurement machine and found to be 5.24mm with a field of view of 128°. Therefore, the miniaturization ratio is at most 1.204 (6.31/5.24).

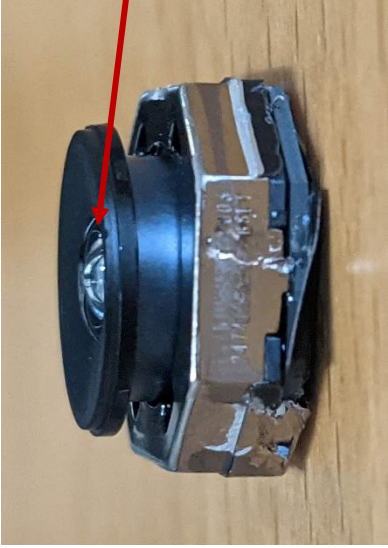
<u>Claim</u>	<u>Apple iPhone 13 Mini Smartphone</u>
a non-linear targeted resolution to intentionally create a zone in an image captured by the miniature wide-angle optical apparatus with a lower or higher object to image magnification compared to linear targeted resolution,	The resolution of the wide-angle lens from the iPhone 13 Mini was measured with the Optikos LensCheck measurement machine. As seen in the graph created by the data captured by the Optikos, the resolution is non-linear and is targeted to maximize magnification within approximately 25° of the edge of the field of view. This non-linear targeted resolution creates a zone in the image with lower object-to-image magnification and a zone with higher object-to-image magnification compared to the linear resolution.

Claim	Apple iPhone 13 Mini Smartphone																																
the lower or higher object to image magnification being used to compensate, at least in part, for a lower image quality due to at least one of a drop of relative illumination or a drop of MTF in a zone of the image,	<table border="1"> <caption>Data points for Average MTF at 100lp/mm</caption> <thead> <tr> <th>Half field of view angle (degree)</th> <th>MTF (%)</th> </tr> </thead> <tbody> <tr><td>0</td><td>90</td></tr> <tr><td>5</td><td>88</td></tr> <tr><td>10</td><td>86</td></tr> <tr><td>15</td><td>84</td></tr> <tr><td>20</td><td>82</td></tr> <tr><td>25</td><td>80</td></tr> <tr><td>30</td><td>82</td></tr> <tr><td>35</td><td>78</td></tr> <tr><td>40</td><td>75</td></tr> <tr><td>45</td><td>70</td></tr> <tr><td>50</td><td>65</td></tr> <tr><td>55</td><td>60</td></tr> <tr><td>60</td><td>55</td></tr> <tr><td>65</td><td>50</td></tr> <tr><td>70</td><td>40</td></tr> </tbody> </table> The image quality, as demonstrated by the MTF measurements shown above, in the zone having a higher object-to-image magnification (greater than about 33 degrees from center) is lower than in the center zone of the image, where there is a lower object to image magnification. This graph shows data captured by the Optikos Lenscheck measurement machine. Specifically, the graph shows the average of the Sagittal and Tangential MTFs measured at 100 lp/mm. The MTF is seen to drop sharply after about 30 degrees from center to a minimum at the edge of the field of view, which mainly coincides with the highest resolution areas of the lens. The non-linear targeted resolution therefore compensates, at least in part, for the lower image quality in this zone of the image. Based on data measured on the Optikos measurement machine, the total field of view of the lens is almost 130°. See, e.g., the graphs of resolution and MTF above, which show half-field view angles reaching nearly 65°. Further, based on Apple’s own product literature, the “ultra wide” camera has a field of view of at least 120°. See https://www.apple.com/iphone-13/specs/.	Half field of view angle (degree)	MTF (%)	0	90	5	88	10	86	15	84	20	82	25	80	30	82	35	78	40	75	45	70	50	65	55	60	60	55	65	50	70	40
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an opening angle of light entering the optical apparatus being over 100°.																																	

<u>Claim</u>	<u>Apple iPhone 13 Mini Smartphone</u>
3. The miniature wide-angle optical apparatus of claim 1, wherein a targeted resolution curve has a change of direction near an edge of a field of view.	The graph displays the resolution performance of the iPhone 13 mini. The y-axis, labeled 'Resolution', ranges from 0 to 60 units per degree. The x-axis, labeled 'FOV (°)', ranges from -80 to 80 degrees. A horizontal red line at approximately 45 units/° represents the 'Linear (UL)' resolution. The blue dots represent the 'iPhone 13 mini (UL)' resolution curve. This curve starts at approximately 45 units/° at -80° FOV, remains relatively constant until about -45°, then increases to a peak of about 55 units/° at 0° FOV, and finally decreases back to about 45 units/° at 80° FOV. A red circle and arrow point to the region near the edge of the field of view (around 60-63° FOV) where the resolution curve changes direction, indicating a non-linear relationship. As can be seen in the graph of the non-linear resolution, the targeted resolution of the iPhone 13 Mini generally increases from the center to a half-field angle of about 45°, remains generally constant from about 45° to about 62°, then abruptly and significantly decreases just near the edge of view around 63°.

Claim	Apple iPhone 13 Mini Smartphone																
4. The miniature wide-angle optical apparatus of claim 1, wherein an angle of chief-rays reaching the focal plane is over 20° from an optical axis of the optical apparatus.	Chief Ray Angle Versus Field Angle <table border="1"> <caption>Approximate data points from the graph</caption> <thead> <tr> <th>Field Angle (°)</th> <th>Chief Ray Angle (°)</th> </tr> </thead> <tbody> <tr><td>0</td><td>0</td></tr> <tr><td>10</td><td>5</td></tr> <tr><td>20</td><td>12</td></tr> <tr><td>30</td><td>20</td></tr> <tr><td>40</td><td>28</td></tr> <tr><td>50</td><td>38</td></tr> <tr><td>60</td><td>45</td></tr> </tbody> </table> The graph above shows data captured by the Optikos LensCheck – a graph of chief ray angle against the field angle of the lens. As can be seen, the angle of chief rays reaching the image sensor in the iPhone 13 Mini exceeds 20° for over half of the field angles, reaching over 40° at its maximum near the edge of the field of view.	Field Angle (°)	Chief Ray Angle (°)	0	0	10	5	20	12	30	20	40	28	50	38	60	45
Field Angle (°)	Chief Ray Angle (°)																
0	0																
10	5																
20	12																
30	20																
40	28																
50	38																
60	45																

<u>Claim</u>	<u>Apple iPhone 13 Mini Smartphone</u>
5. The miniature wide-angle optical apparatus of claim 1, further comprising a plurality of optical elements, at least one of the plurality of optical elements defining the first surface.	Apple's website lists the wide-angle optical apparatus of the iPhone 13 Mini as having a "five-element lens." See https://www.apple.com/iphone-13/specs/. When the camera module is removed from the phone and the protective glass cover is removed from the lens, one can see that the outermost lens element is the light receiving first surface. 
7. The miniature wide-angle optical apparatus of claim 1, wherein the miniaturization ratio value is less than 2.0.	As noted above, the miniaturization ratio was calculated to be at most 1.204, which is less than 2.0.

<u>Claim</u>	<u>Apple iPhone 13 Pro Smartphone</u>
1. A miniature wide-angle optical apparatus comprising:	The iPhone 13 Pro has a wide-angle camera with a wide-angle lens including the features listed below.
a light-receiving first surface;	 First surface of the lens The wide-angle lens has a first surface receiving light.
a focal plane;	In a digital camera, an image sensor is placed approximately at the focal plane of the objective lens in order to obtain a focused image. The wide-angle lens from the iPhone 13 Pro necessarily has a focal plane, as evidenced by the placement of an image sensor that obtains a clear, focused image.  Lens Image Sensor Photograph of iPhone 13 Pro camera module disassembled.

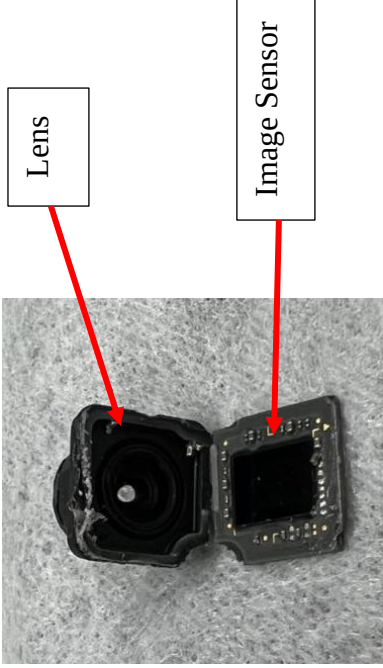
<u>Claim</u>	<u>Apple iPhone 13 Pro Smartphone</u>
a total track length measured from a center of the first surface to the focal plane;	 The distance from the first surface to the image sensor was measured at a maximum of 6.40 mm. Because the image sensor sits approximately at the focal plane, the total track length is measured from the first surface to the image sensor and therefore is at most 6.40 mm.
a miniaturization ratio with a value less than 3.0, the miniaturization ratio being a ratio of the total track length divided by an image circle diameter; and	The total track length, as measured above, is at most 6.40 mm. The image circle diameter was measured via the Optikos LensCheck measurement machine and found to be 5.38mm with a field of view of 133°. Therefore, the miniaturization ratio is at most 1.19 (6.40/5.38).

Claim	Apple iPhone 13 Pro Smartphone																											
a non-linear targeted resolution to intentionally create a zone in an image captured by the miniature wide-angle optical apparatus with a lower or higher object to image magnification compared to linear targeted resolution,	Lower Object-to-Image Magnification Zone Higher Object-to-Image Magnification Zone <table><caption>Approximate data points from the graph</caption><thead><tr><th>Half field of view angle (degree)</th><th>Resolution (µm/degree) - iPhone 13 Pro</th><th>Resolution (µm/degree) - Linear</th></tr></thead><tbody><tr><td>0</td><td>30</td><td>30</td></tr><tr><td>10</td><td>30</td><td>30</td></tr><tr><td>20</td><td>30</td><td>30</td></tr><tr><td>30</td><td>35</td><td>35</td></tr><tr><td>40</td><td>45</td><td>45</td></tr><tr><td>50</td><td>55</td><td>55</td></tr><tr><td>60</td><td>55</td><td>55</td></tr><tr><td>70</td><td>55</td><td>55</td></tr></tbody></table> The resolution of the wide-angle lens from the iPhone 13 Pro was measured with the Optikos LensCheck measurement machine. As seen in the graph created by the data captured by the Optikos, the resolution is non-linear and is targeted to maximize magnification within a range of about 32° to about 62° of the field of view. This non-linear targeted resolution creates a zone in the image with lower object-to-image magnification and a zone with higher object-to-image magnification compared to the linear resolution.	Half field of view angle (degree)	Resolution (µm/degree) - iPhone 13 Pro	Resolution (µm/degree) - Linear	0	30	30	10	30	30	20	30	30	30	35	35	40	45	45	50	55	55	60	55	55	70	55	55
Half field of view angle (degree)	Resolution (µm/degree) - iPhone 13 Pro	Resolution (µm/degree) - Linear																										
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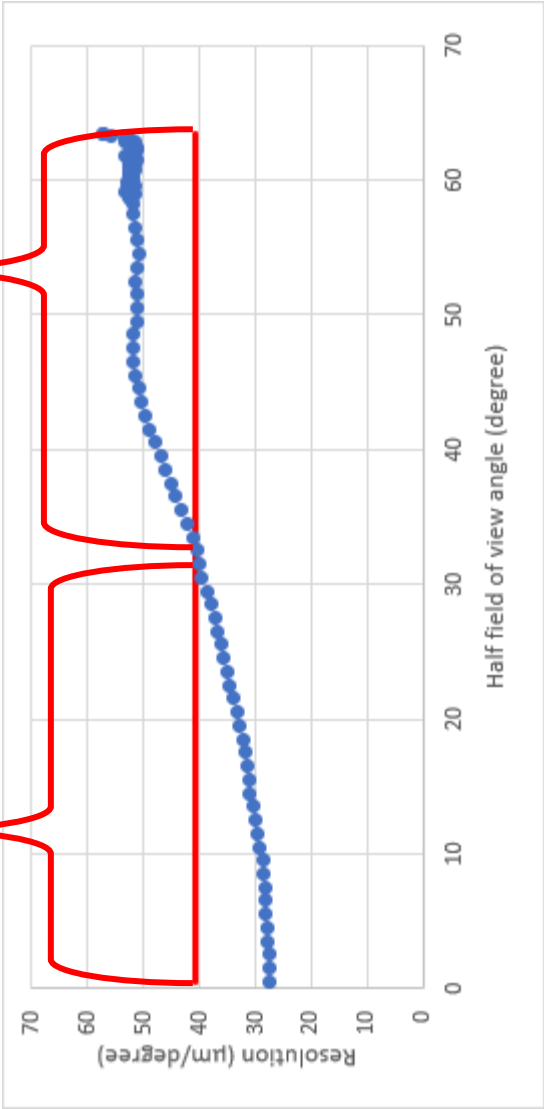
<u>Claim</u>	<u>Apple iPhone 13 Pro Smartphone</u>																																				
the lower or higher object to image magnification being used to compensate, at least in part, for a lower image quality due to at least one of a drop of relative illumination or a drop of MTF in a zone of the image,	<table border="1"> <caption>Approximate data points from the MTF graph</caption> <thead> <tr> <th>Half field of view angle (degree)</th> <th>MTF (%)</th> </tr> </thead> <tbody> <tr><td>0</td><td>90</td></tr> <tr><td>5</td><td>90</td></tr> <tr><td>10</td><td>90</td></tr> <tr><td>15</td><td>90</td></tr> <tr><td>20</td><td>90</td></tr> <tr><td>25</td><td>90</td></tr> <tr><td>30</td><td>90</td></tr> <tr><td>32</td><td>90</td></tr> <tr><td>33</td><td>90</td></tr> <tr><td>35</td><td>90</td></tr> <tr><td>40</td><td>90</td></tr> <tr><td>45</td><td>90</td></tr> <tr><td>50</td><td>90</td></tr> <tr><td>55</td><td>90</td></tr> <tr><td>60</td><td>90</td></tr> <tr><td>65</td><td>90</td></tr> <tr><td>70</td><td>90</td></tr> </tbody> </table> The image quality, as demonstrated by the MTF measurements shown above, in the zone having a higher object-to-image magnification (greater than about 32° to about 62° from center) is lower than in the center zone of the image, where there is a lower object to image magnification. This is most pronounced in the range of about 50° to about 60° from center. This graph shows data captured by the Optikos Lenscheck measurement machine. Specifically, the graph shows the average of the Sagittal and Tangential MTFs measured at 100 lp/mm. The MTF is seen to drop sharply continuously from center to about 50°, and drop sharply after about 50° degrees from center to a minimum around 60° from center, before rising slightly. This mainly coincides with the highest resolution areas of the lens around 50° from center. The non-linear targeted resolution therefore compensates, at least in part, for the lower image quality in this zone of the image. Based on data measured on the Optikos measurement machine, the total field of view of the lens is about 133°. See, e.g., the graphs of resolution and MTF above, which show half-field view angles reaching over 65°. Further, based on Apple’s own product literature, the “ultra wide” camera has a field of view of at least 120°. See https://www.apple.com/am/iphone-13-pro/specs/.	Half field of view angle (degree)	MTF (%)	0	90	5	90	10	90	15	90	20	90	25	90	30	90	32	90	33	90	35	90	40	90	45	90	50	90	55	90	60	90	65	90	70	90
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an opening angle of light entering the optical apparatus being over 100°.																																					

<u>Claim</u>	<u>Apple iPhone 13 Pro Smartphone</u>
3. The miniature wide-angle optical apparatus of claim 1, wherein a targeted resolution curve has a change of direction near an edge of a field of view.	Resolution (µm/degree) Half field of view angle (degree) iPhone 13 Pro Linear resolution Change of direction As can be seen in the graph of the non-linear resolution, the targeted resolution of the iPhone 13 Pro generally increases from the center to a half-field angle of about 50° and decreases near the edge of the field of view around 50°.

<u>Claim</u>	<u>Apple iPhone 13 Pro Smartphone</u>
5. The miniature wide-angle optical apparatus of claim 1, further comprising a plurality of optical elements, at least one of the plurality of optical elements defining the first surface.	Apple's website lists the wide-angle optical apparatus of the iPhone 13 Pro as having a "six-element lens." See https://www.apple.com/am/iphone-13-pro/specs/. When the camera module is removed from the phone and the protective glass cover is removed from the lens, one can see that the outermost lens element is the light receiving first surface. 
7. The miniature wide-angle optical apparatus of claim 1, wherein the miniaturization ratio value is less than 2.0.	As noted above, the miniaturization ratio was calculated to be at most 1.19, which is less than 2.0.

<u>Claim</u>	<u>Apple iPhone 14 Smartphone</u>
1. A miniature wide-angle optical apparatus comprising:	The iPhone 14 has a wide-angle camera with a wide-angle lens including the features listed below.
a light-receiving first surface;	 The wide-angle lens has a first surface receiving light.
a focal plane;	In a digital camera, an image sensor is placed approximately at the focal plane of the objective lens in order to obtain a focused image. The wide-angle lens from the iPhone 14 necessarily has a focal plane, as evidenced by the placement of an image sensor that obtains a clear, focused image.  Photograph of iPhone 14 camera module disassembled.

<u>Claim</u>	<u>Apple iPhone 14 Smartphone</u>
a total track length measured from a center of the first surface to the focal plane;	 The distance from the first surface to the image sensor was measured at a maximum of 7.03 mm. Because the image sensor sits approximately at the focal plane, the total track length is measured from the first surface to the image sensor and therefore is at most 7.03 mm.
a miniaturization ratio with a value less than 3.0, the miniaturization ratio being a ratio of the total track length divided by an image circle diameter; and	The total track length, as measured above, is at most 7.03 mm. The image circle diameter was measured via the Optikos LensCheck measurement machine and found to be 5.15mm with a field of view of 126.5°. Therefore, the miniaturization ratio is at most 1.365 (7.03/5.15).

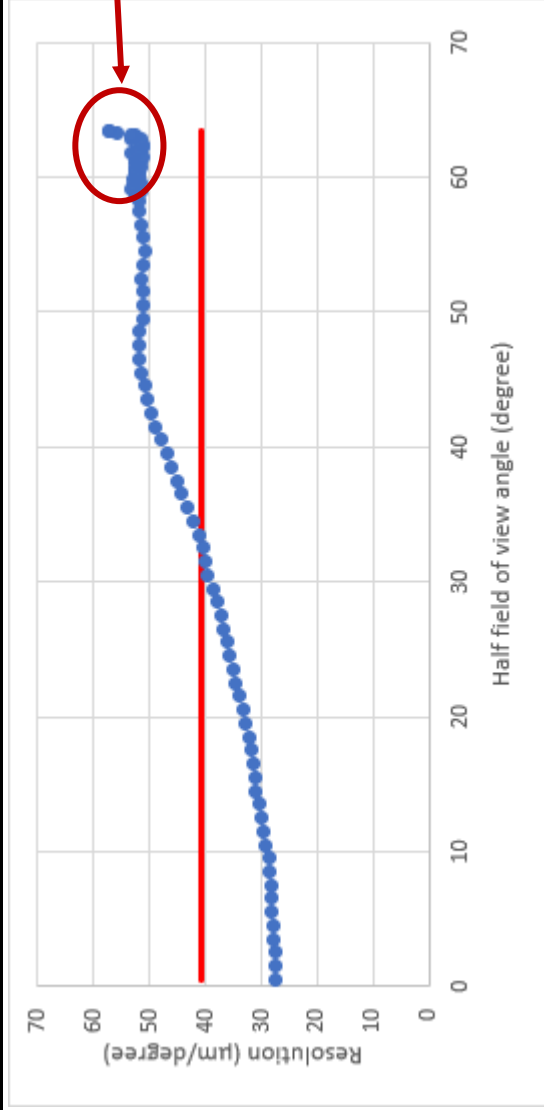
Claim	Apple iPhone 14 Smartphone
a non-linear targeted resolution to intentionally create a zone in an image captured by the miniature wide-angle optical apparatus with a lower or higher object to image magnification compared to linear targeted resolution,	Lower Object-to-Image Magnification Zone Higher Object-to-Image Magnification Zone  The resolution of the wide-angle lens from the iPhone 14 was measured with the Optikos LensCheck measurement machine. As seen in the graph created by the data captured by the Optikos, the resolution is non-linear and is targeted to maximize magnification within approximately 20° of the edge of the field of view. This non-linear targeted resolution creates a zone in the image with lower object-to-image magnification and a zone with higher object-to-image magnification compared to the linear resolution.

Claim	Apple iPhone 14 Smartphone																																
the lower or higher object to image magnification being used to compensate, at least in part, for a lower image quality due to at least one of a drop of relative illumination or a drop of MTF in a zone of the image,	<table border="1"> <caption>Data points for Average MTF at 100lp/mm</caption> <thead> <tr> <th>Half field of view angle (degree)</th> <th>MTF (%)</th> </tr> </thead> <tbody> <tr><td>0</td><td>85</td></tr> <tr><td>5</td><td>82</td></tr> <tr><td>10</td><td>70</td></tr> <tr><td>15</td><td>65</td></tr> <tr><td>20</td><td>45</td></tr> <tr><td>25</td><td>48</td></tr> <tr><td>30</td><td>52</td></tr> <tr><td>35</td><td>45</td></tr> <tr><td>40</td><td>50</td></tr> <tr><td>45</td><td>42</td></tr> <tr><td>50</td><td>48</td></tr> <tr><td>55</td><td>45</td></tr> <tr><td>60</td><td>52</td></tr> <tr><td>65</td><td>20</td></tr> <tr><td>70</td><td>25</td></tr> </tbody> </table> The image quality, as demonstrated by the MTF measurements shown above, in the zone having a higher object-to-image magnification (greater than about 33 degrees from center) is lower than in the center zone of the image, where there is a lower object to image magnification. This graph shows data captured by the Optikos Lenscheck measurement machine. Specifically, the graph shows the average of the Sagittal and Tangential MTFs measured at 100 lp/mm. The MTF is seen to drop sharply after about 30 degrees from center to a minimum at the edge of the field of view, which mainly coincides with the highest resolution areas of the lens. The non-linear targeted resolution therefore compensates, at least in part, for the lower image quality in this zone of the image. Based on data measured on the Optikos measurement machine, the total field of view of the lens is almost 130°. See, e.g., the graphs of resolution and MTF above, which show half-field view angles reaching nearly 65°. Further, based on Apple's own product literature, the "ultra wide" camera has a field of view of at least 120°. See https://www.apple.com/iphone-14/specs/.	Half field of view angle (degree)	MTF (%)	0	85	5	82	10	70	15	65	20	45	25	48	30	52	35	45	40	50	45	42	50	48	55	45	60	52	65	20	70	25
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Apple iPhone 14 Smartphone

Claim

3. The miniature wide-angle optical apparatus of claim 1, wherein a targeted resolution curve has a change of direction near an edge of a field of view.

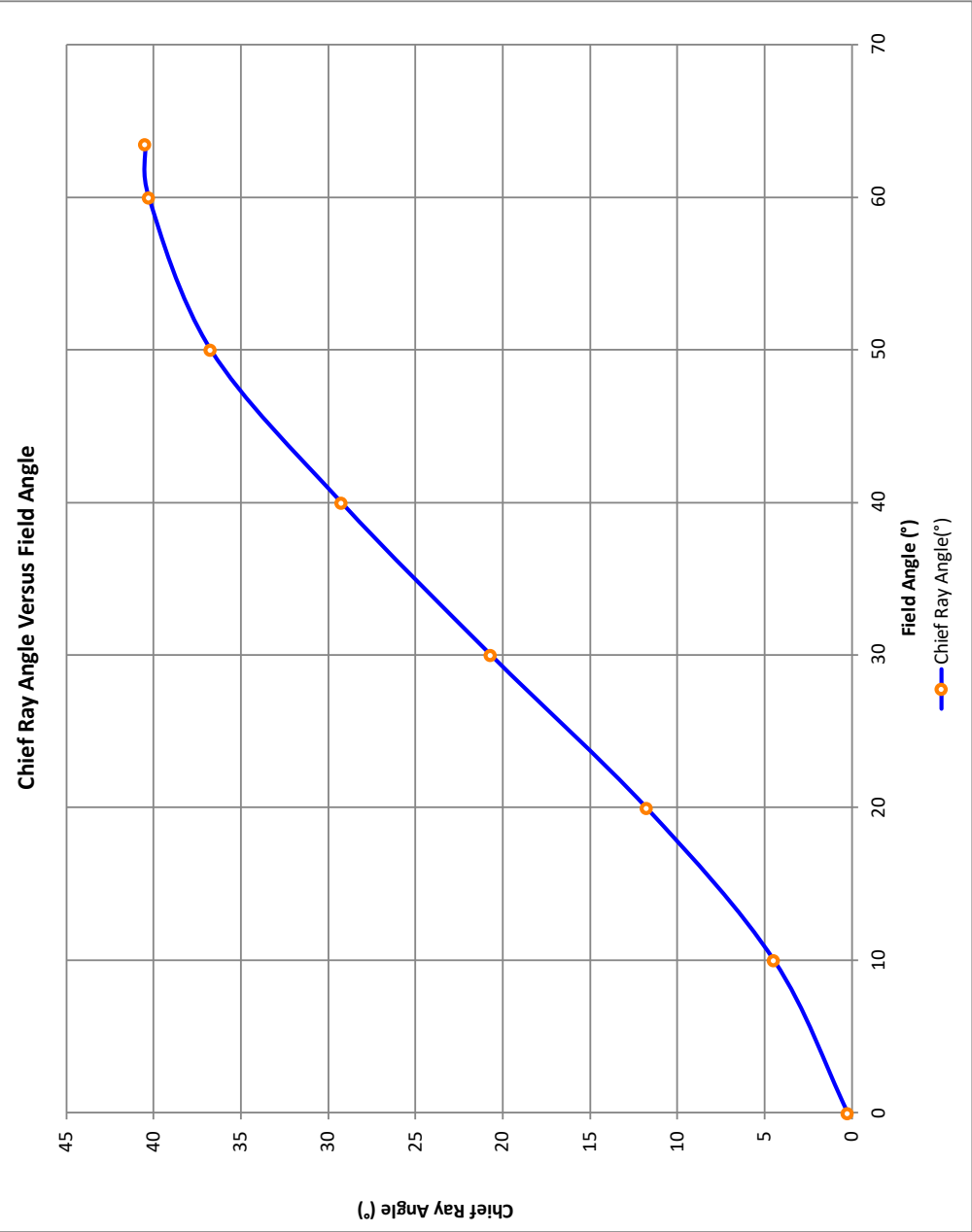


As can be seen in the graph of the non-linear resolution, the targeted resolution of the iPhone 14 generally increases from the center to a half-field angle of about 45°, remains constant from about 45° to about 62°, then abruptly and significantly increases just near the edge of the field of view around 63°.

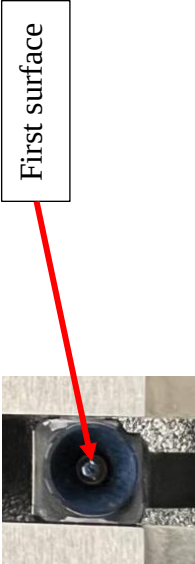
Apple iPhone 14 Smartphone

Claim

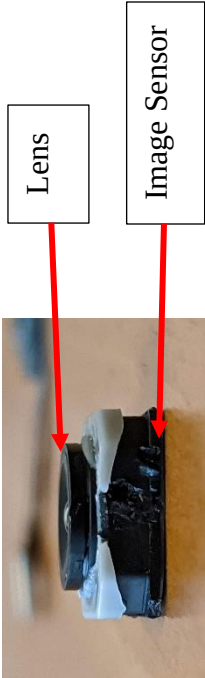
4. The miniature wide-angle optical apparatus of claim 1, wherein an angle of chief-rays reaching the focal plane is over 20° from an optical axis of the optical apparatus.

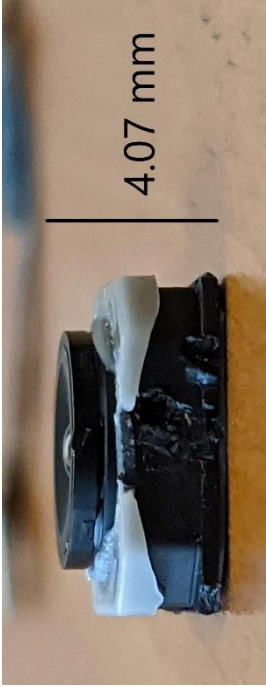


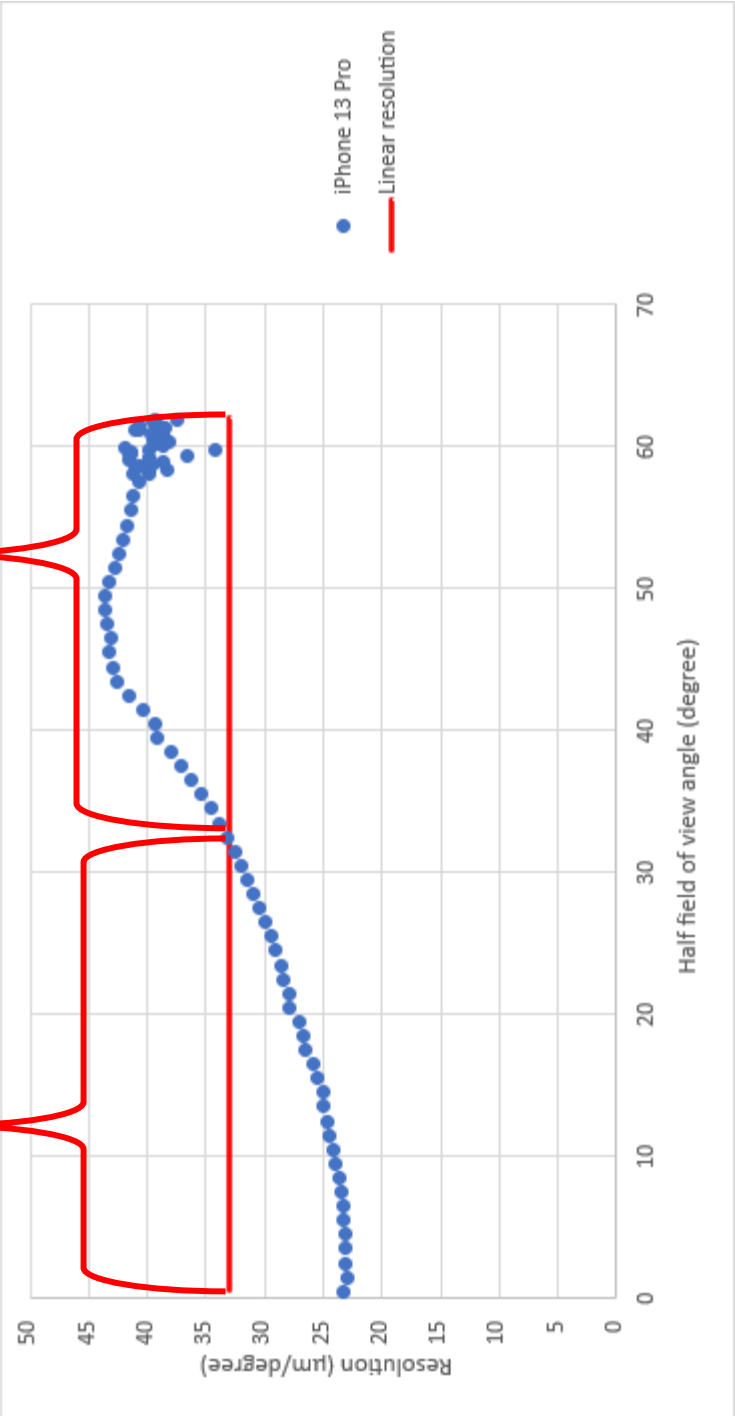
The graph above shows data captured by the Optikos LensCheck – a graph of chief ray angle against the field angle of the lens. As can be seen, the angle of chief rays reaching the image sensor in the iPhone 14 exceeds 20° for over half of the field angles, reaching over 40° at its maximum near the edge of the field of view.

<u>Claim</u>	<u>Apple iPhone 14 Smartphone</u>
5. The miniature wide-angle optical apparatus of claim 1, further comprising a plurality of optical elements, at least one of the plurality of optical elements defining the first surface.	Apple's website lists the wide-angle optical apparatus of the iPhone 14 as having a "five-element lens." See https://www.apple.com/iphone-14/specs/. When the camera module is removed from the phone and the protective glass cover is removed from the lens, one can see that the outermost lens element is the light receiving first surface. 
7. The miniature wide-angle optical apparatus of claim 1, wherein the miniaturization ratio value is less than 2.0.	As noted above, the miniaturization ratio was calculated to be at most 1.365, which is less than 2.0.

US PATENT 10,795,120 v. APPLE IPAD PRO

<u>Claim</u>	<u>Apple iPad Pro Tablet</u>
1. A miniature wide-angle optical apparatus comprising:	The iPad Pro has a wide-angle camera with a wide-angle lens including the features listed below.
a light-receiving first surface;	 First surface The wide-angle lens has a first surface receiving light.
a focal plane;	In a digital camera, an image sensor is placed approximately at the focal plane of the objective lens in order to obtain a focused image. The wide-angle lens from the iPad Pro necessarily has a focal plane, as evidenced by the placement of an image sensor that obtains a clear, focused image.  Lens Image Sensor Photograph of iPad Pro camera module.

<u>Claim</u>	<u>Apple iPad Pro Tablet</u>
a total track length measured from a center of the first surface to the focal plane;	 The distance from the first surface to the image sensor was measured at a maximum of 4.07 mm. Because the image sensor sits approximately at the focal plane, the total track length is measured from the first surface to the image sensor and therefore is at most 4.07 mm.
a miniaturization ratio with a value less than 3.0, the miniaturization ratio being a ratio of the total track length divided by an image circle diameter; and	The total track length, as measured above, is at most 4.07 mm. The image circle diameter was measured via the Optikos LensCheck measurement machine and found to be 4.09 mm with a field of view of 124°. Therefore, the miniaturization ratio is at most 0.995 (4.07/4.09).

Claim	Apple iPad Pro Tablet
a non-linear targeted resolution to intentionally create a zone in an image captured by the miniature wide-angle optical apparatus with a lower or higher object to image magnification compared to linear targeted resolution,	Lower Object-to-Image Magnification Zone Higher Object-to-Image Magnification Zone  The resolution of the wide-angle lens from the iPad Pro was measured with the Optikos LensCheck measurement machine. As seen in the graph¹ created by the data captured by the Optikos, the resolution is non-linear and is targeted to maximize magnification within approximately 30° of the edge of the field of view. This non-linear targeted resolution creates a zone in the image with lower object-to-image magnification and a zone with higher object-to-image magnification compared to the linear resolution.

¹ Note that the notation in the legend of “iPhone 13 Pro” is a typographical error. The data was captured on the iPad Pro.

Claim	Apple iPad Pro Tablet																																
the lower or higher object to image magnification being used to compensate, at least in part, for a lower image quality due to at least one of a drop of relative illumination or a drop of MTF in a zone of the image,	<table border="1"> <caption>Data points estimated from the graph</caption> <thead> <tr> <th>Half field of view angle (degree)</th> <th>MTF (%)</th> </tr> </thead> <tbody> <tr><td>0</td><td>92</td></tr> <tr><td>5</td><td>91</td></tr> <tr><td>10</td><td>90</td></tr> <tr><td>15</td><td>89</td></tr> <tr><td>20</td><td>88</td></tr> <tr><td>25</td><td>86</td></tr> <tr><td>30</td><td>84</td></tr> <tr><td>35</td><td>82</td></tr> <tr><td>40</td><td>78</td></tr> <tr><td>45</td><td>74</td></tr> <tr><td>50</td><td>70</td></tr> <tr><td>55</td><td>66</td></tr> <tr><td>60</td><td>62</td></tr> <tr><td>65</td><td>58</td></tr> <tr><td>70</td><td>40</td></tr> </tbody> </table> The image quality, as demonstrated by the MTF measurements shown above, in the zone having a higher object-to-image magnification (greater than about 33 degrees from center) is lower than in the center zone of the image, where there is a lower object to image magnification. This graph shows data captured by the Optikos Lenscheck measurement machine. Specifically, the graph shows the average of the Sagittal and Tangential MTFs measured at 100 lp/mm. The MTF is seen to drop sharply after about 35 degrees from center to a minimum at the edge of the field of view, which mainly coincides with the highest resolution areas of the lens. The non-linear targeted resolution therefore compensates, at least in part, for the lower image quality in this zone of the image. Based on data measured on the Optikos measurement machine, the total field of view of the lens is almost 130°. See, e.g., the graphs of resolution and MTF above, which show half-field view angles reaching nearly 65°. Further, based on Apple’s own product literature, the “ultra wide” camera has a field of view of at least 125°. See https://support.apple.com/kb/SP844?locale=en_US.	Half field of view angle (degree)	MTF (%)	0	92	5	91	10	90	15	89	20	88	25	86	30	84	35	82	40	78	45	74	50	70	55	66	60	62	65	58	70	40
Half field of view angle (degree)	MTF (%)																																
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10	90																																
15	89																																
20	88																																
25	86																																
30	84																																
35	82																																
40	78																																
45	74																																
50	70																																
55	66																																
60	62																																
65	58																																
70	40																																
an opening angle of light entering the optical apparatus being over 100°.																																	

Claim	Apple iPad Pro Tablet
3. The miniature wide-angle optical apparatus of claim 1, wherein a targeted resolution curve has a change of direction near an edge of a field of view.	Resolution (µm/degree) Half field of view angle (degree) iPhone 13 Pro Linear resolution Change of direction As can be seen in the graph of the non-linear resolution, the targeted resolution of the iPad Pro generally increases from the center to a half-field angle of about 50°, slowly decreases from about 50° to about 58°, then abruptly varies near the edge of the field of view around 58-63°.

<u>Claim</u>	<u>Apple iPad Pro Tablet</u>
5. The miniature wide-angle optical apparatus of claim 1, further comprising a plurality of optical elements, at least one of the plurality of optical elements defining the first surface.	Apple's website lists the wide-angle optical apparatus of the iPad Pro as having a "five-element lens." See https://support.apple.com/kb/SP844?locale=en_US. When the camera module is removed from the phone and the protective glass cover is removed from the lens, one can see that the outermost lens element is the light receiving first surface. 
7. The miniature wide-angle optical apparatus of claim 1, wherein the miniaturization ratio value is less than 2.0.	As noted above, the miniaturization ratio was calculated to be at most 0.995, which is less than 2.0.