Nocturnality

NVD Optical Lens Selection and Performance Evaluation

Dec 29th, 2024

Optical lenses are an important part of a complete night vision system, acting as the components which form the output of an image intensifier into a visually consumable image by a human observer. A complete night vision device requires two different lenses to function - an objective lens and an eyepiece (sometimes called an “ocular”) lens.

For the history of its existence in the United States, commercially owned night vision systems have often been sold either as complete goods from key suppliers of the core technology, such as L3Harris, or as custom buildable systems utilizing components sourced through the DoD supply chain. As the industry has grown, however, supply of critical components including device housings, and optical lenses, have become available from suppliers not currently (or historically, ever) supplying the DoD or its partners directly.

In the case of optical lenses used in night vision systems, this has been a point of interest for commercial buyers, because these components have a direct and obvious impact on the overall quality of a night vision system itself while being one of the few relatively simple components which could be provided by a multitude of potential sources worldwide. Indeed, optical lenses are critical to the health of the overall industry, because without their supply, there are no functional night vision devices. Alternatively, with a supply of subpar quality lenses, commercially available night vision systems would be less desirable and capable than their potential.

Therefore, the selection of lenses used in the manufacture of complete night vision systems is of key importance. In addition to the need for quality in these components, for the commercial night vision industry there is also a need for resilient supply of such components. Recently

around the time of writing of this paper, a key supplier of these optical lenses for NVDs ceased operating, constricting the supply. Because the commercial NVD market has historically relied solely on DoD suppliers for optical lenses, there suddenly became a clear need for supply resiliency, because government buyers could easily monopolize the supply of a critical component for NVD manufacture, throttling the commercial availability of night vision technology.

Therefore it has become important to secure the health of the commercial NV industry to establish supply of similar quality optical lens components from providers who are not necessarily required to divert supply to government customers when called upon. Beginning in 2022 and through 2024, this has been achieved, and many suppliers including Nocturnality have begun utilizing both objective and eyepiece optical lenses for night vision systems from suppliers who are not current DoD suppliers. In the case of Nocturnality, this was done only after extensively testing available supply for comparable quality to the existing status-quo of lenses used by DoD partners.

This paper demonstrates the verification of quality for alternative optical lenses used in the commercial night vision industry for those used by Nocturnality and many other suppliers today. A series of key tests were performed with results imaged and recorded using cutting edge night vision test equipment (Hoffman Engineering 126A).

Currently Approved Suppliers of Optical Lenses for NVDs by Nocturnality

Nocturnality currently assembles its night vision systems utilizing optical lenses from the following providers:

For Objective Lenses, we have tested and approved use of - Fujinon (industry historical standard and DoD supplier for Noctis), Rochester Precision Optics, Steele Industries, Night Vision Devices, Nightline Inc. In the case of the latter three suppliers, the manufacturer of the lenses are NDA protected and the named companies are merely distributors.

For Eyepiece Lenses, we have tested and approved use of - Fujinon, Salvo Technologies, Rochester Precision Optics

In this paper we are demonstrating the quality testing results primarily for objective lenses supplied by Steele Industries, and eyepiece lenses supplied by Salvo Technologies, because these suppliers are U.S. based, providing comparably priced components to DoD suppliers, and have open distribution to many night vision manufacturers.

Description of Tests Performed

Two categories of tests are performed by Nocturnality when selecting optical lenses to be used in assembly of complete night vision systems.

Optical quality tests performed and demonstrated in this paper include distortion testing, vignetting testing, resolution testing, and lens flare testing.

System functionality tests performed include collimation testing and vacuum seal testing.

For the purposes of this paper, we are primarily focused on the optical quality tests, because system functionality tests are pass/fail and a pass is required to even have the optical quality tests performed. By extension, all approved optics mentioned above have passed all system functionality tests and no further demonstration or description is feasible.

All optical tests were performed with the same image intensifier tube, using the controlled lighting capability of the Hoffman 126A test set, and images were captured utilizing an iPhone 12 and hard mounting equipment directly to the test NVD itself. In each case, all efforts were made to establish the best optical fidelity as possible (i.e. focus, diopter setting, lens alignments, etc).

The image intensifier tube used to generate the images in the test device was an L3Harris Gen 3 unfilmed image tube with the following tested specifications:

SNR = 34.7, Center resolution = 72 lp/mm, EBI = 0.4 x10-11 phot, Halo = 0.8mm, High Light Resolution = 36 lp/mm

In each optical quality test, a 'control' setup and test was performed using all Fujinon lenses, because these have been one of the longstanding providers of proven quality lenses used around the NV industry for decades. Variables were introduced in the form of alternative manufacturers lenses, both by introducing either a different objective lens or eyepiece lens while keeping the other lens the 'known quantity' of Fujinon to show the effects of introducing only the one singular new product. In addition, the same tests were performed utilizing the combination of both an alternative objective lens and eyepiece lens in combination, with no use of Fujinon, as this combination is common in the industry and in use by Nocturnality today.

Distortion Testing Results

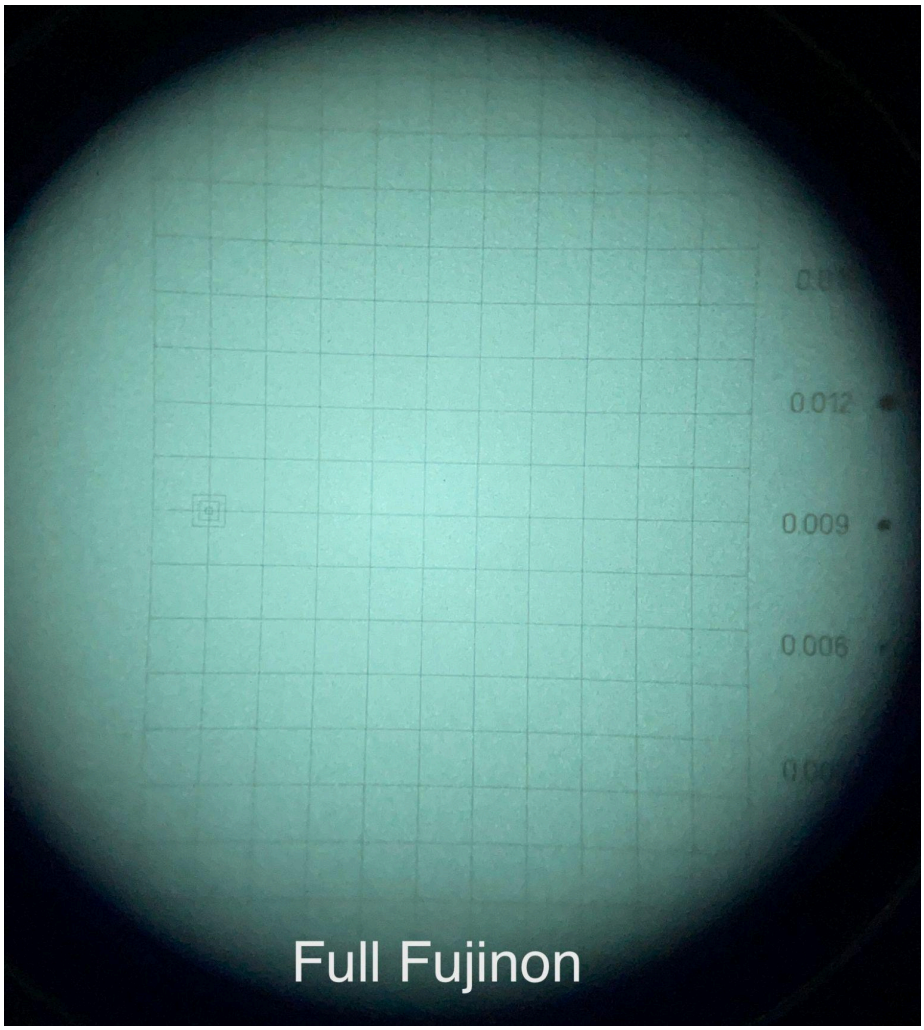
Lenses for NVDs can cause a distorted effect in the image the user sees depending on the quality and design of the lens materials used. Edge distortion, or the low resolution effect seen only at the very edges of a night vision device image, is an accepted and universal phenomenon regardless of lenses used. What can differ, however, is the degree of this edge distortion. In addition, certain low quality lenses (not demonstrated in these tests) can also distort the image in the center in a bubble-like effect.

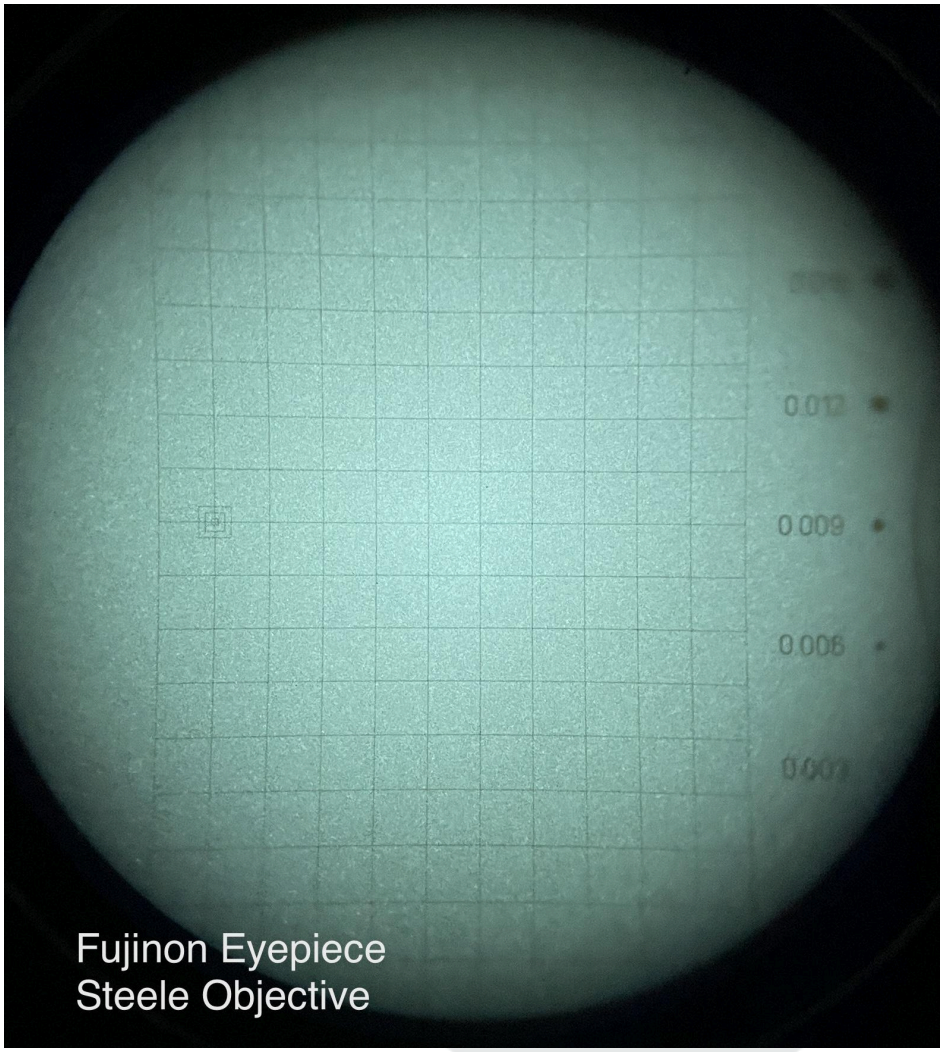
To test both types of distortions, the Hoffman 126 utilizes a grid pattern distortion testing reticle to show any central or bubble distortions a device may have as a result of lenses selected. Edge

distortion is also directly comparable using the standard spot-chart reticle of the machine which shows a concentric circles pattern in accordance with standard ‘zone’ image defect testing for dark spots in an image intensifier. In this reticle, typically the outer edge distortion caused by lenses is easily viewed and compared.

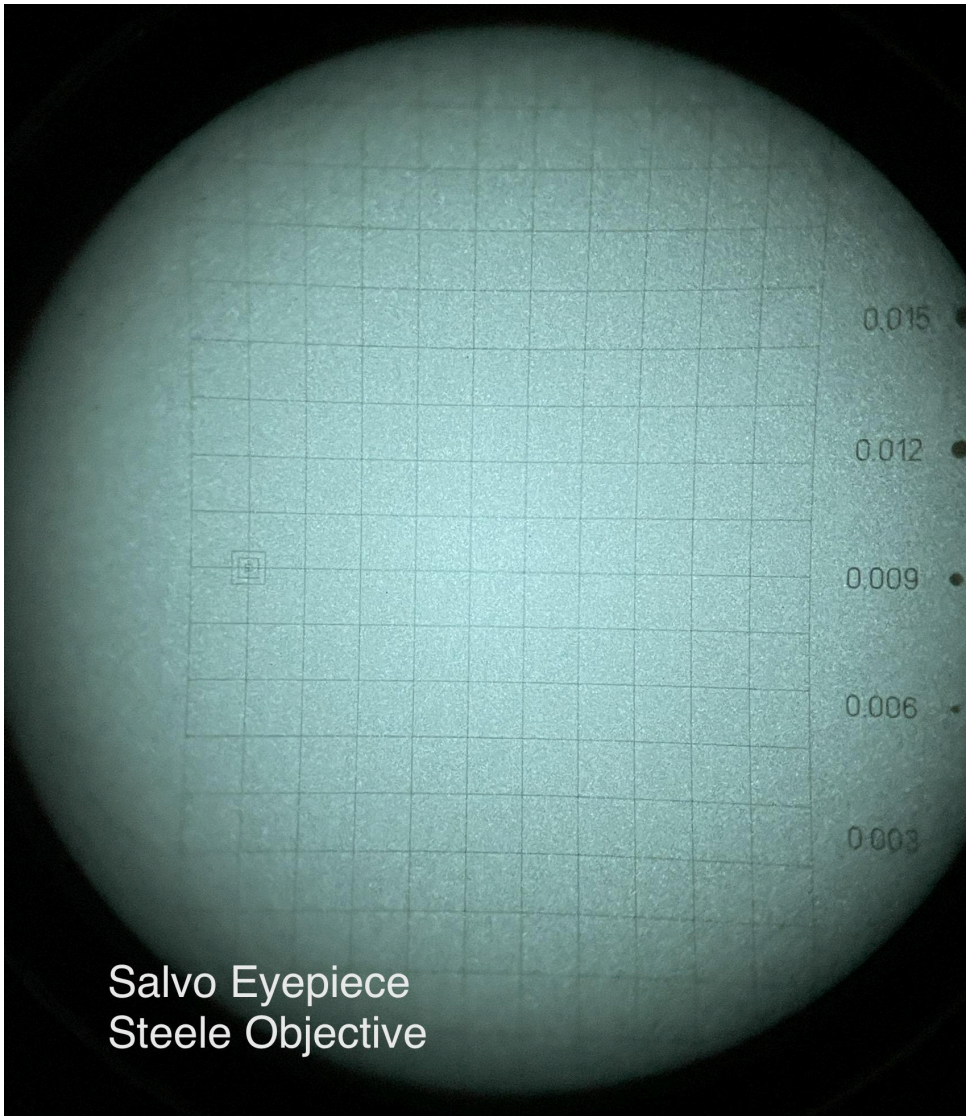
Grid Pattern (Central and Edge Distortion) Tests

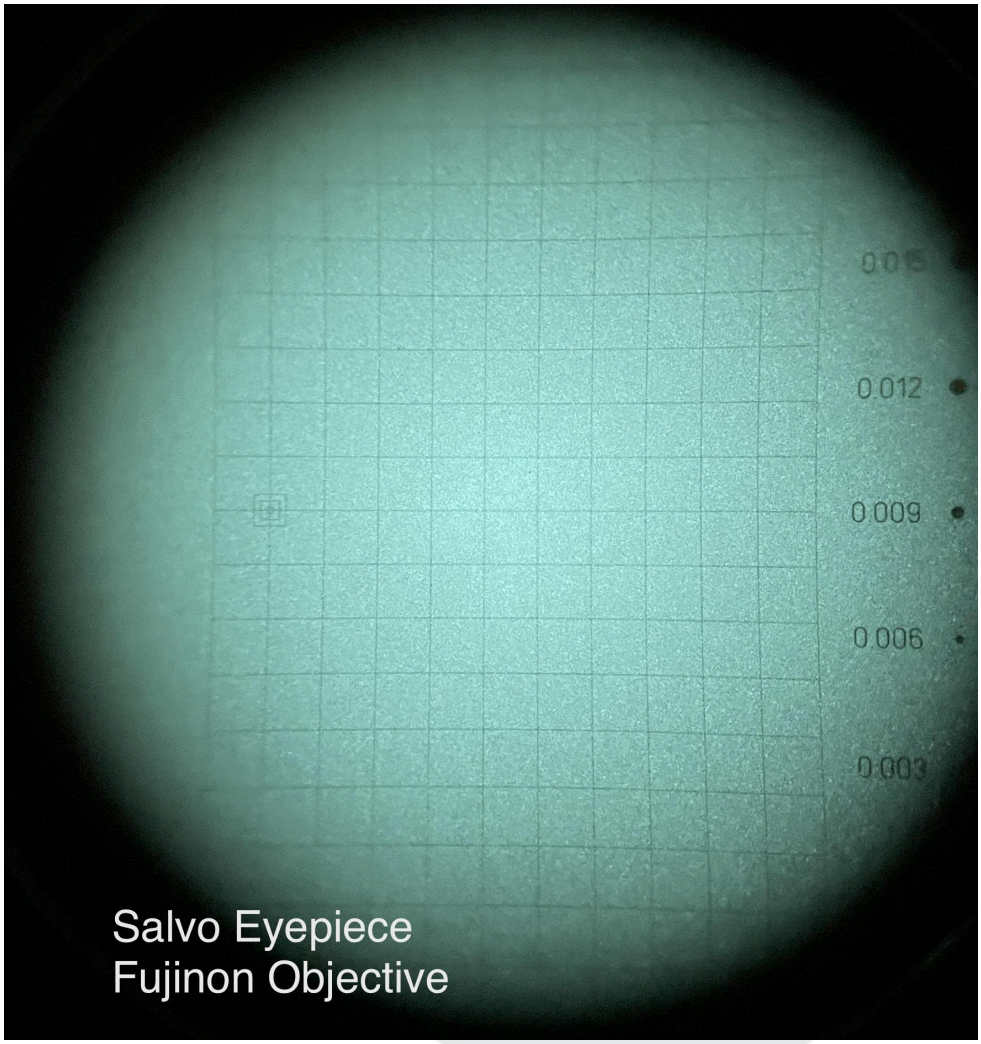
Full Fujinon - Control Setup





Fujinon Eyepiece
Steele Objective

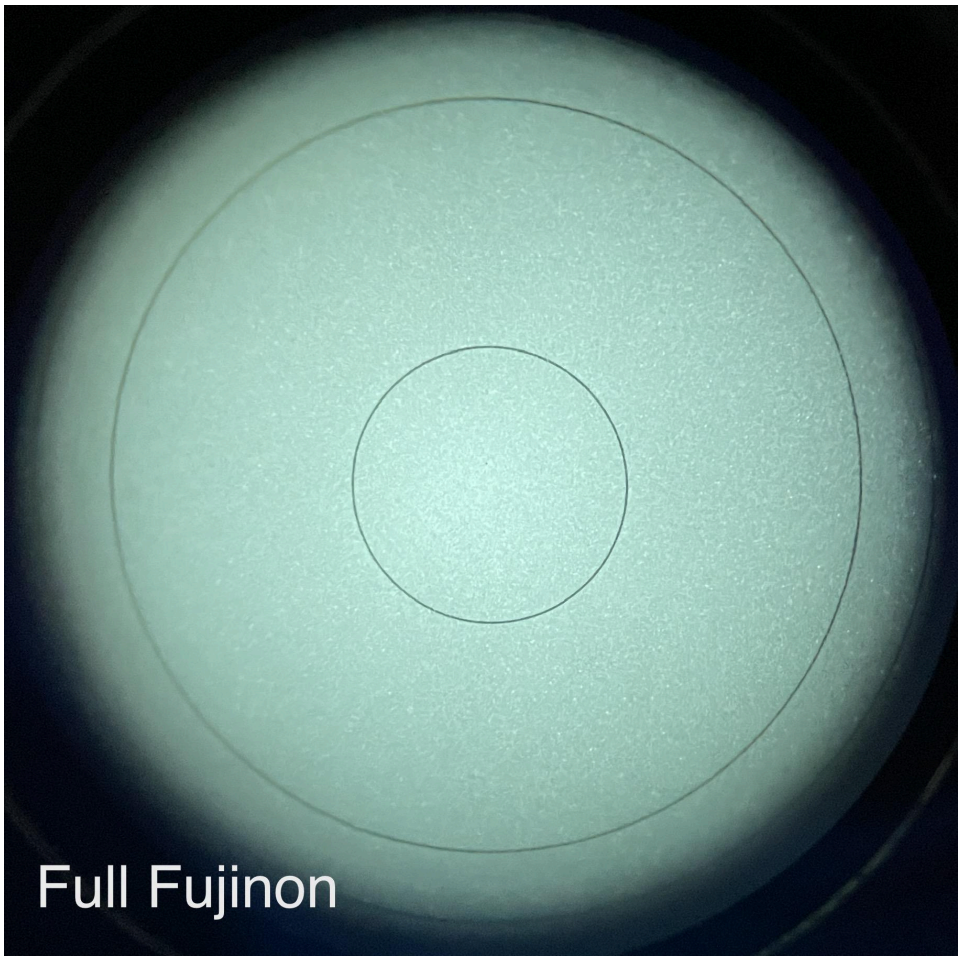

0.015
0.012
0.009
0.006
0.003
Salvo Eyepiece
Steele Objective

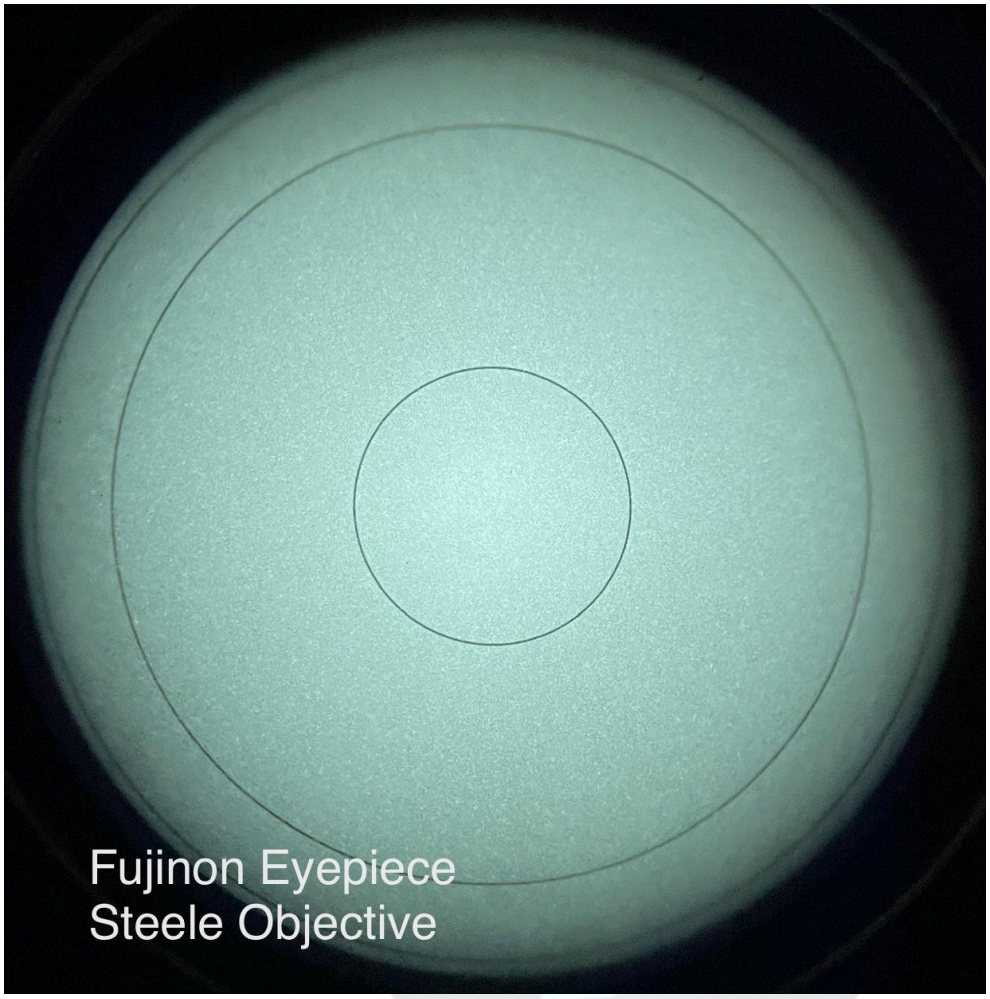


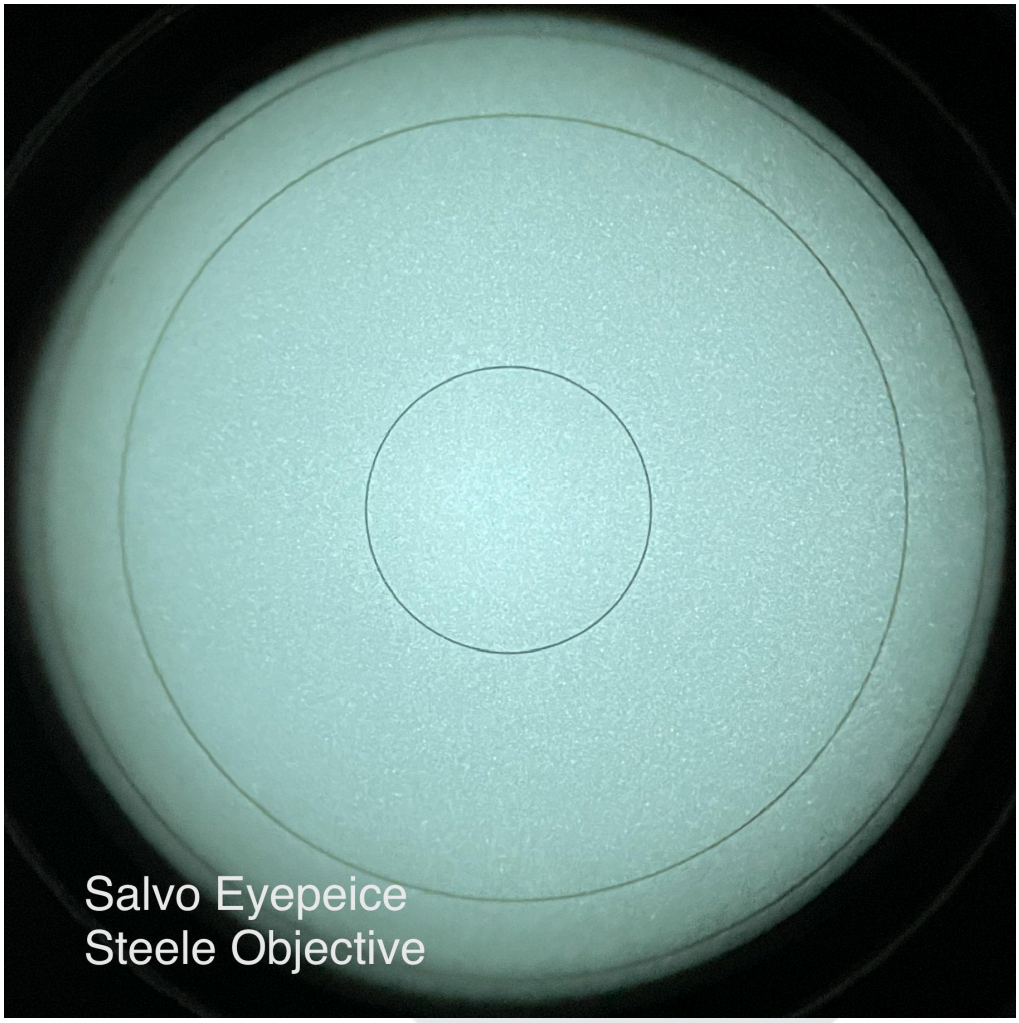
Salvo Eyepiece
Fujinon Objective

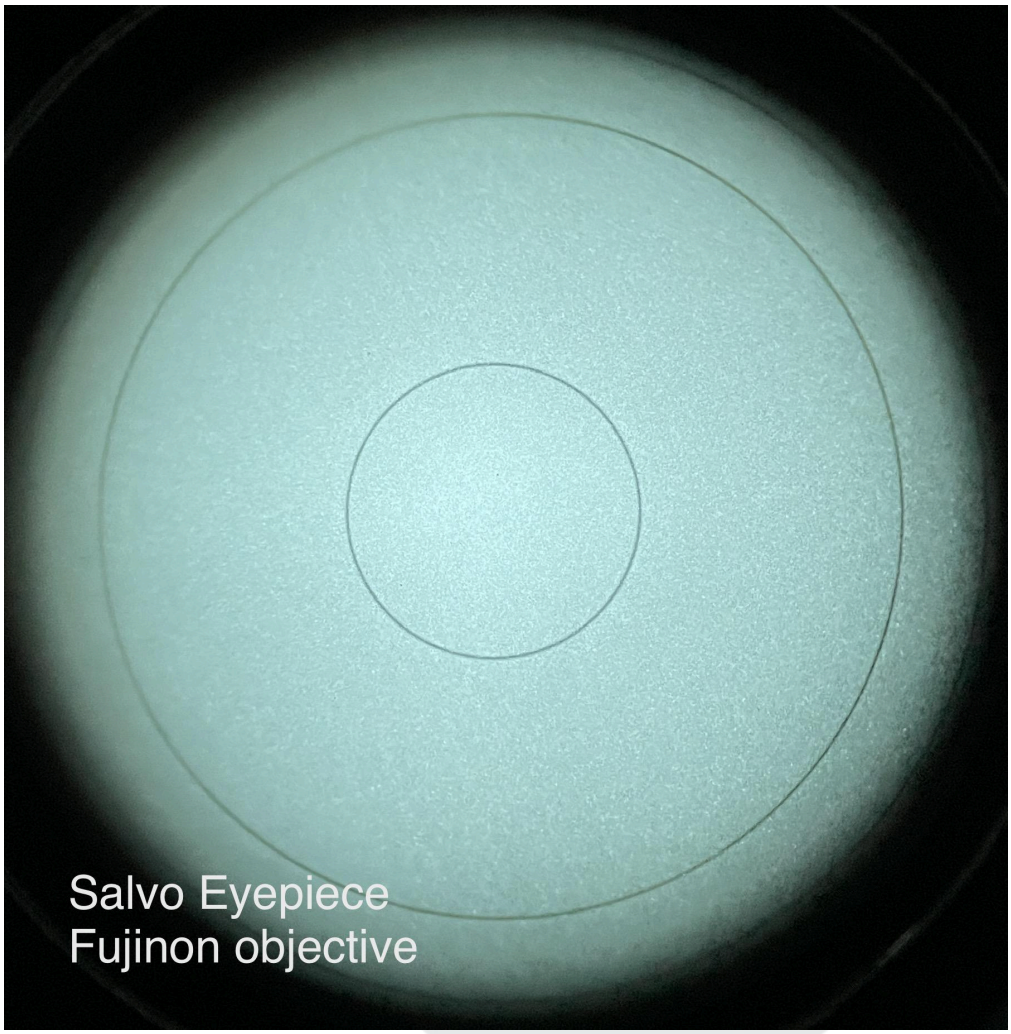
Zone Pattern (Edge Distortion) Tests

The zone test pattern provides a means to better identify edge distortion, which is present in all night vision optics to some degree as evidenced by the control setup of using ‘industry standard’ Fujinon eyepiece and objective lens combo below.



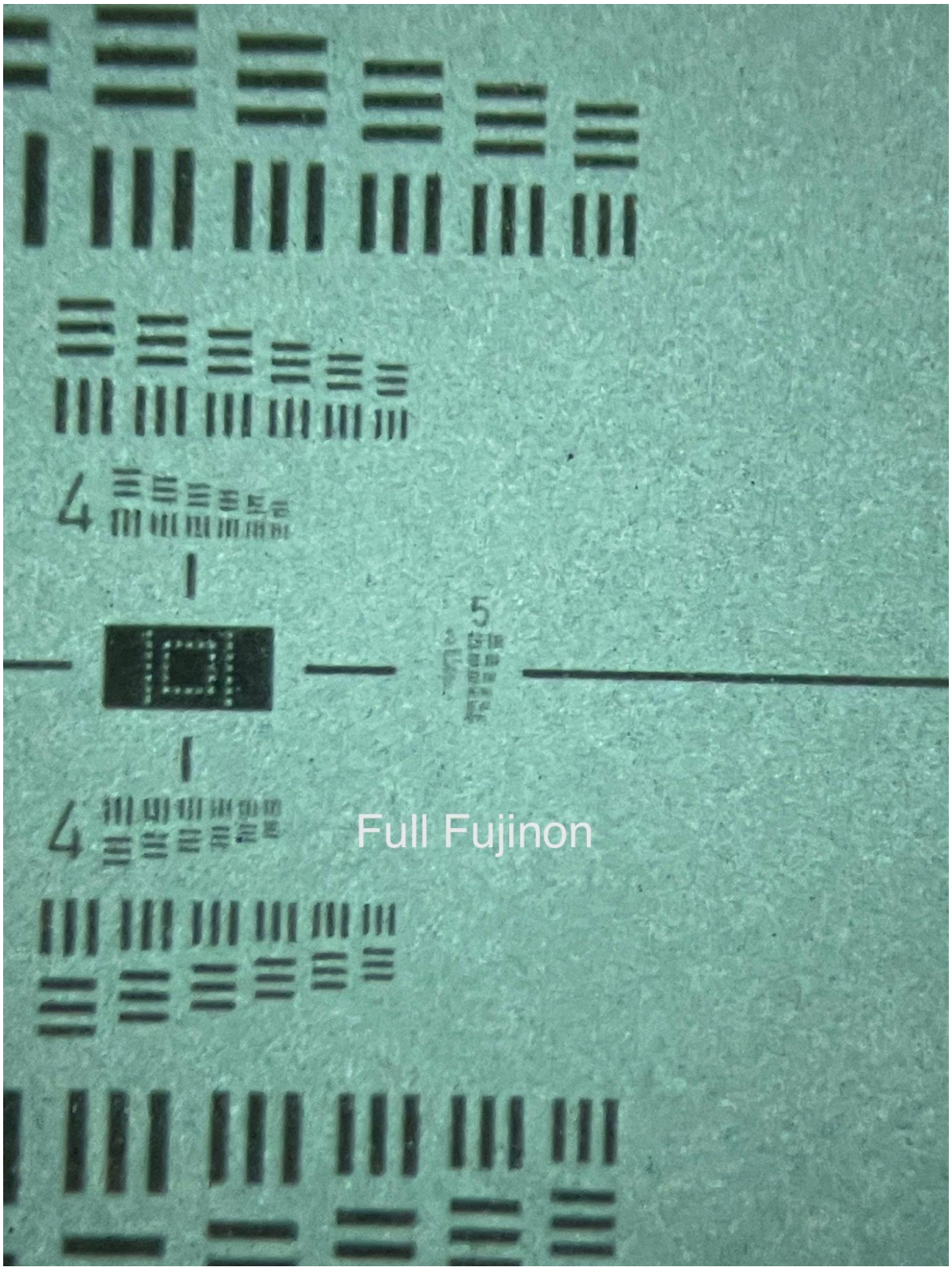

Fujinon Eyepiece
Steele Objective

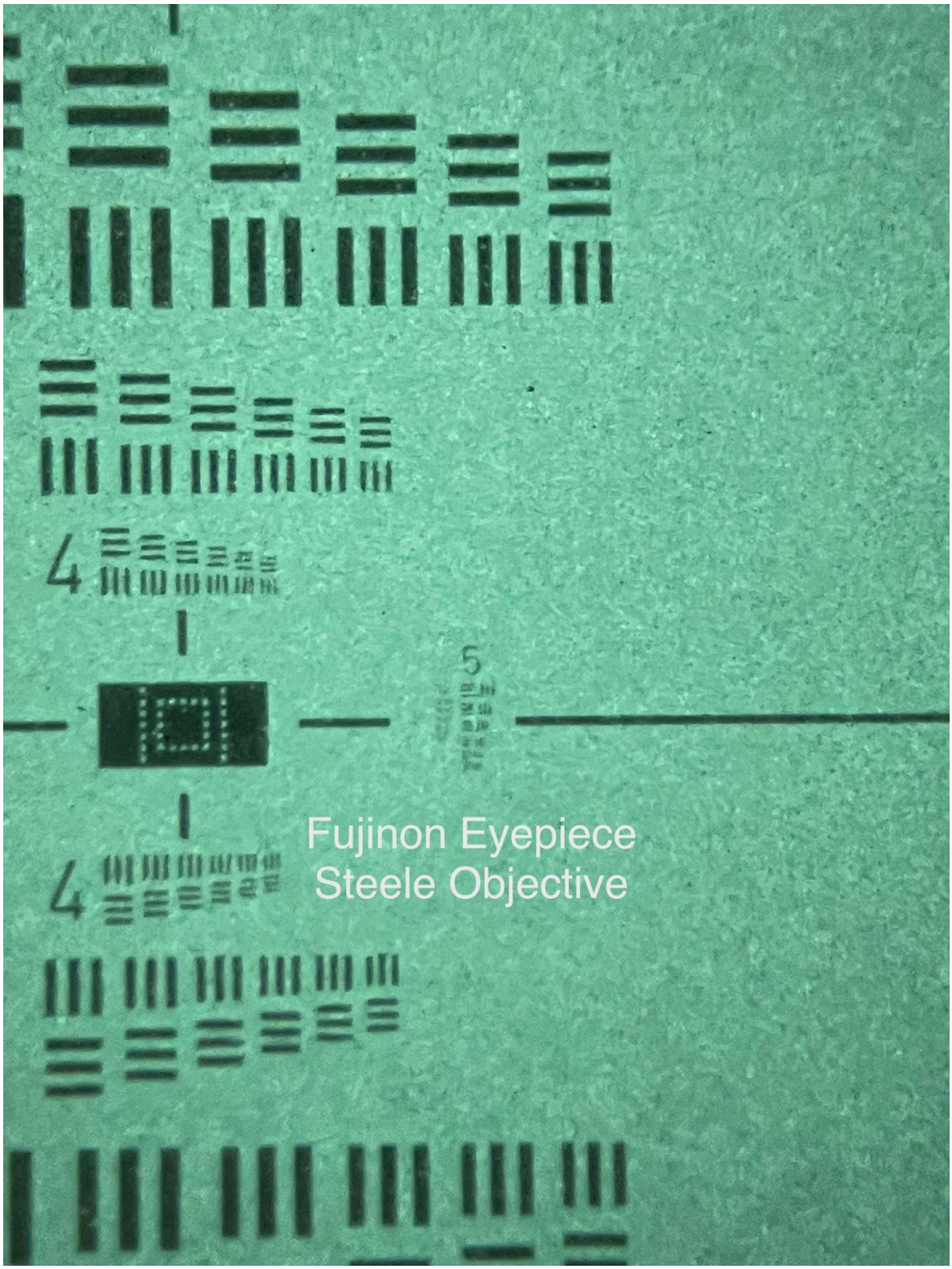

Salvo Eyepeice
Steele Objective

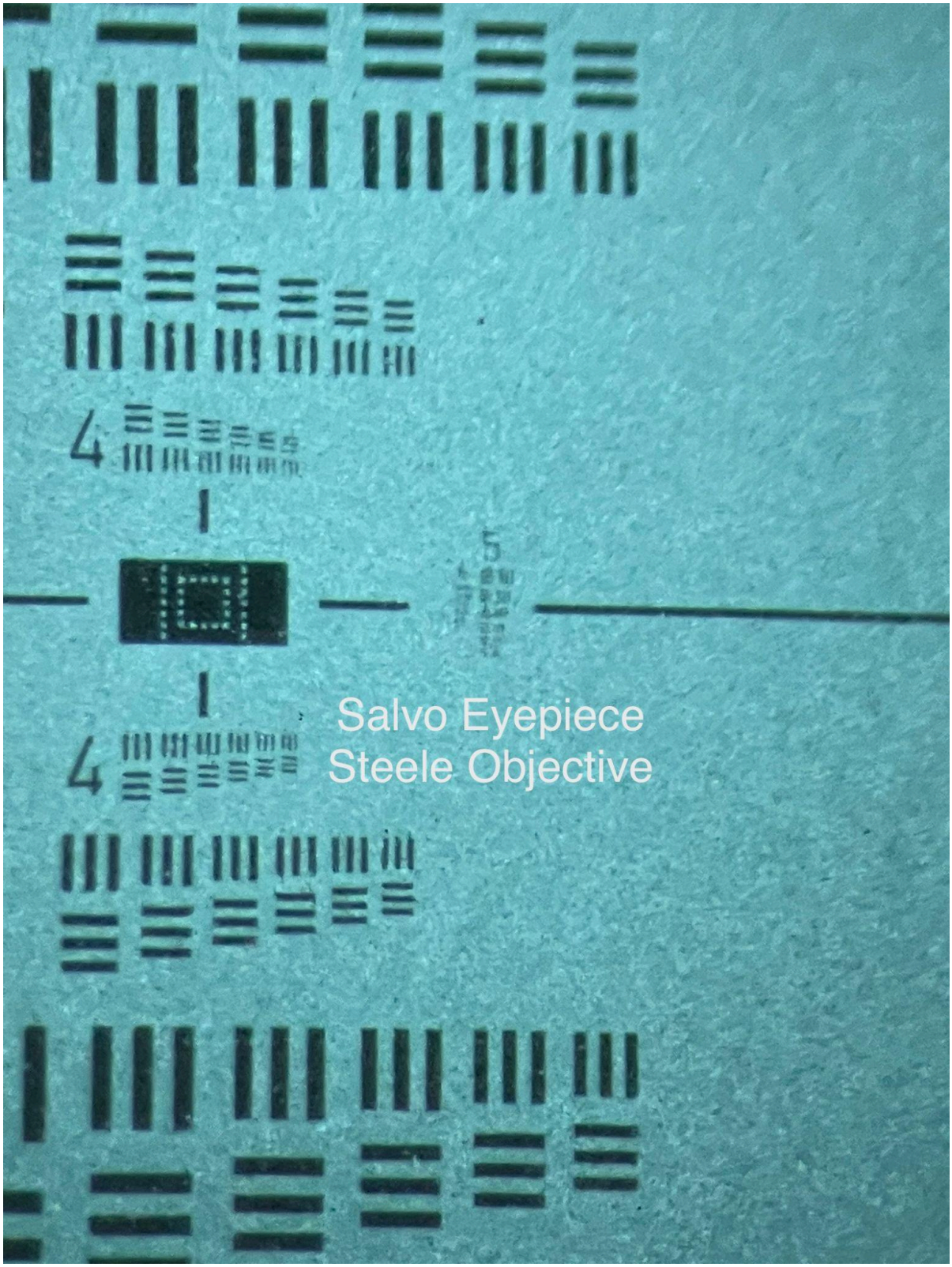

Salvo Eyepiece
Fujinon objective

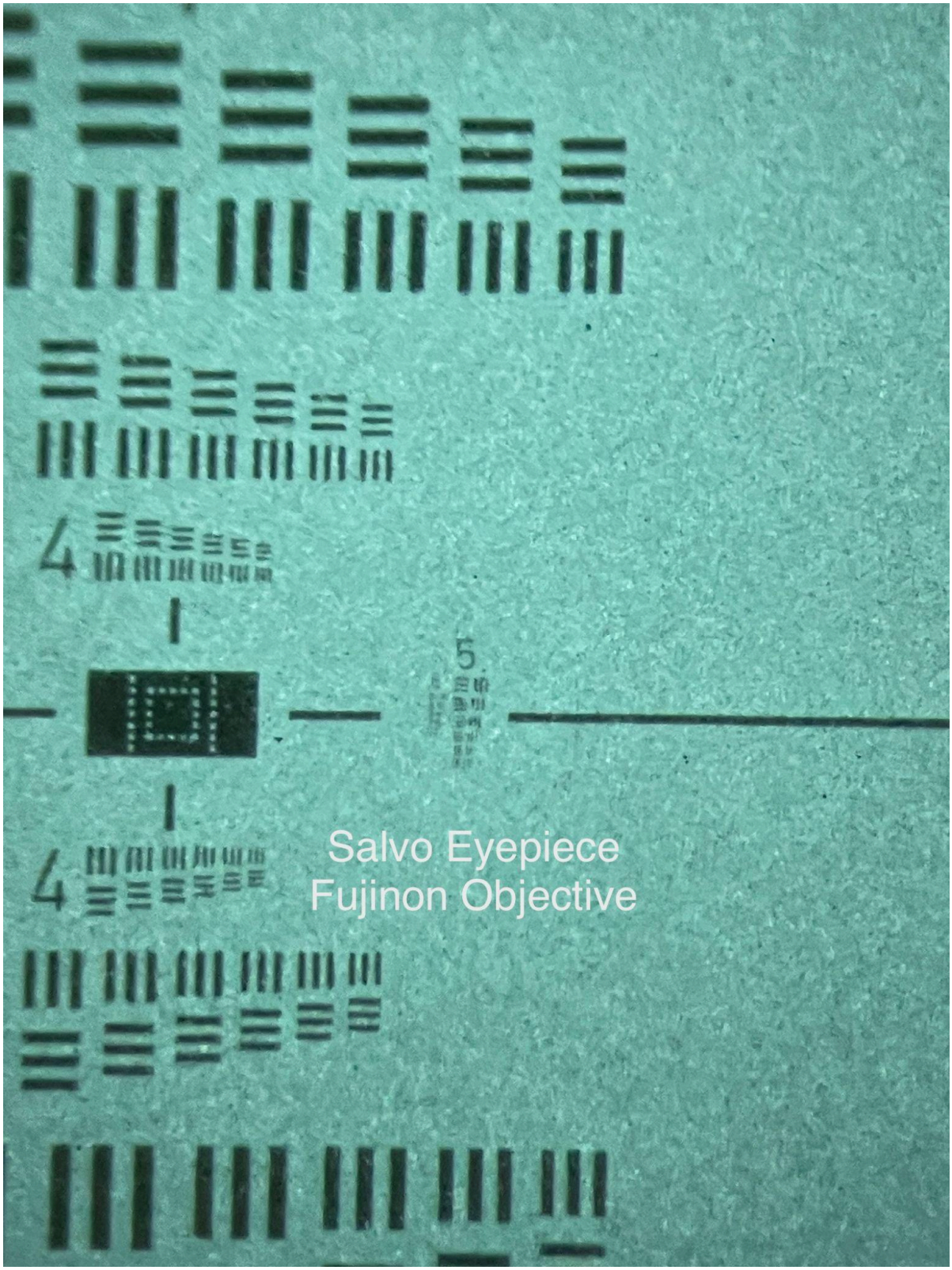
Resolution Pattern Tests

The following images were shot on 5x magnification with the smallest identifiable test group (Group 5) in the central focus area of the image. Because of the importance of properly setting the manual focus of the device to even be able to identify details this small, multiple images were taken for each optical setup and then the best selected from each that were all of consistent ‘best possible’ output quality.


4
5
4
Full Fujinon


4
5
4
Fujinon Eyepiece
Steele Objective

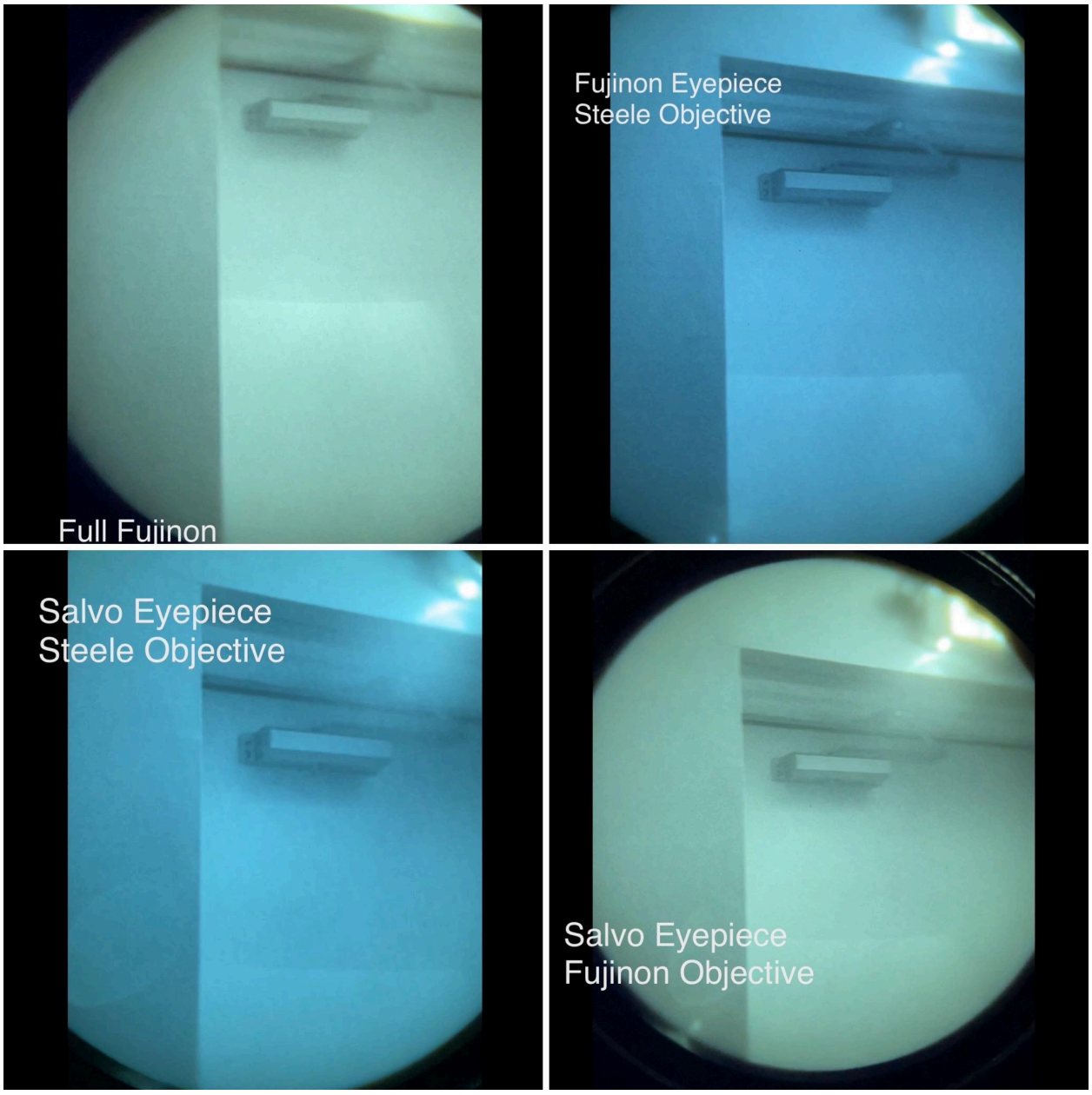

4
5
4
Salvo Eyepiece
Steele Objective


4
5
4
Salvo Eyepiece
Fujinon Objective

Lens Flare Suppression Testing

To demonstrate the evaluation of lens flaring that the objective optics may demonstrate, video was taken by mounting the test PVS14 device in identical optical setups as used in the images above, to capture footage through the device when aimed around intensely bright light sources. When lens flare is present in a night vision device, it tends to be worse when a bright light source is viewed just off the edge of the viewing area, allowing the flare effect to appear over the primary central viewing area.

The below screen images were captured from the respective videos to show any flare artifacts at their worst for each combination.


Full Fujinon
Fujinon Eyepiece
Steele Objective
Salvo Eyepiece
Steele Objective
Salvo Eyepiece
Fujinon Objective

Conclusion and Acknowledgements

Throughout optical quality and system functionality testing performed, very little differences in optical quality could be observed even with intense, purposeful scrutiny, utilizing any of the optic choices shown including both those from DoD approved 'milspec' suppliers and approved newer non DoD optical manufacturers. All optical quality characteristics were consistent across lenses used. Some minor differences could be observed with intense scrutiny, but not in a way that a clear 'best' could be determined in aggregate across the tests performed when comparing Fujinon against alternatives from Salvo or Steele industries in both objective and eyepiece optical lenses.

The resulting quality of night vision devices can be easily maintained when using optical lens suppliers outside the limited few who currently and historically have supplied the DoD, as long as sufficient testing is performed to confirm the optical quality and the conformity with system functionality requirements for collimation and vacuum seal.

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