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TELESCOPIC SIGHT FOR MOUNTING ON SOLDIER RIFLE

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Abstract: The optical design of the smallest day use telescopic sight in the 0.4µm to 0.7 µm wavelength range for mounting on solider rifle is presented.. The optics of telescopic sight is a nine element design which consists of objective , erector and an eyepiece. The magnification, field- of – view , entrance pupil diameter and exit pupil diameter of the optics are 4.7x, 15.0 degrees,24.0 mm , 4.0mm respectively. The vertex to vertex length of the telescopic sight is 258.3.mm. The eye relief of optics is 42.3mm which is 1.43 times the focal length of eye piece. T he optical system is designed using only four optical glasses in nine elements. The telescopic sight acquires and recognizes 50 -300 meter distant military targets of soldier interest in warfare.. The eleven lenses of optics uses only twelve different radii of curvatures. All the optical surfaces of optics are spherical The physical dimensions of optics for viewing and aiming are dimensioned so that it can be mounted to a rifle with the use of mounting brackets and hardware of a standard size and spacing.

Keywords: Visible spectrum, soldier rifle optical sight, compact telescope

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INTRODUCTION

Refractive optics for telescopic sight is used in a wide variety of applications to obtain increased magnification of scene. In one common application, a viewing and aiming optics is affixed to the upper side of a small arm, in our case, soldier rifle. The soldier sights through the viewing and aiming optics to acquire a target and aim the rifle towards the target to increase the likely hood of hitting the target with a bullet fired from the rifle. The telescopic sight for rifle scope will have limited field –of- view and magnification. The field –of –view and magnification are interlinked for such optics the larger the magnification, the smaller the field of view and vice versa. The field –of- view is smaller than the unaided eye.

In some situations, such as a soldier fighting in warfare, the rifle man is most effective in close range situation, typically less than 50 meters to the target. For intermediate ranges ,typically 50 -300 meters to the targets, the soldier is more effective in viewing the target with a moderate magnification viewing and aiming optics of about 2x -6x magnification using one eye.

The physical dimensions of telescopic sight for viewing and aiming are important to maintain so that it can be mounted to a rifle with the use of mounting brackets and hardware of a standard size and spacing. Light rays in 0.4 µm to 0.7 µm wavelength band reflected or emitted from an observed distant target enter the telescopic sight of soldier rifle through a fixed objective portion passes through each optical element of the telescopic sight and exit the optics through eyepiece for viewing by the soldier. The lens design of telescopic sight for rifle delivers a resolution better than 1.0 minutes of arc in eye relief space for normal optics for day use(or photopic use)for both magnification and field –of- view when the soldier eye at an eye relief distance of >25.0 mm The 1.0 minutes of arc resolution mentioned is also the limiting resolution of human eye of observer under best working conditions. The telescopic sight also delivers long eye relief to avoid the damage of eye due to recoil of rifle. Since the best conditions are not prevailed in ware field, the telescopic sight is designed for 2.0 minutes of arc resolution.

The publication presents the optical design and design data of 252.3 mm vertex to vertex length, 15 degrees field- of –view, 4.7 X, eleven element telescopic sight for mounting on soldier rifle. The reticle is incorporated in objective image plane. The design uses only four optical glasses and seventeen spherical surfaces with twelve different radii values. The all spherical optical design delivers an eye relief of 42.82 mm. The all spherical optics is preferred here because the required numbers of optics are in lakhs and more over it is easy to fabricate and test spherical optics. The parallax error due to the targets at different ranges is made minimum to the desired limits of aiming and viewing. The Centro gravity of the optical elements in the optical path of

telescopic sight is kept at minimum deviation from center of the optical path so that bore sighting error for telescopic sight is minimum.

1. Requirements of optics for mounting on soldier rifle

Requirements of telescopic sight for mounting on soldier rifle is summarized Table 1 and a typical soldier rifle is shown in figure1.

Table 1: Requirements of telescopic sight

Parameter	Value/advantage
wave length range	0.4 µm - 0.7 µm
Magnification (With in the 2x -6x for recognition and acquiring distant targets)	4.7 X
Field – Of- View	15 degrees
Entrance pupil diameter	28.2 mm Minimum
Exit pupil diameter (for various illumination condition of day light)	6.0mm
Vertex To Vertex Length	250+_ 10 mm
Long Eye Relief	>25.0 mm
Parallax error during acquisition of distant targets in 50 – 300 meters range	Low
Resolution of optics (in target space in warfare conditions.)	2.0 Minutes Of Arc
Target Range	50 – 300 Meters
Deviation of centro gravity(cg) of lenses from center of optical path of optics	Minimum

All spherical optics	For easy Of fabrication and testing
Repeated radii of curvature values for optical surfaces for elements in optics	So that the entire optics can be tested with a minimum number of test plates
Sufficient air surfaces between optical elements	For easy assembling of elements in to system

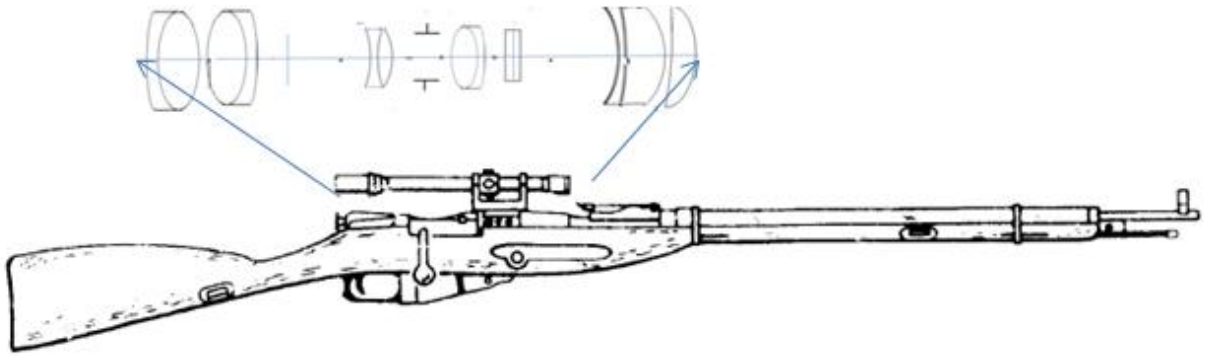

Figure 1: Typical soldier rifle

3.0 Configuration of telescopic sight for rifle mounting

The telescopic sight uses single element and cemented doublet in objective, reticle in objective image plane, two doublet erector with aperture stop in between and two cemented doublet eyepiece The focal length of objective, erector and eyepiece are shown in Table2.

Table 2: Focal length of Objective ,Erector ,Eye piece

Lens system	Focal length
Objective	93.10413 mm
Erector	38.89188 mm
Eye piece	30.01300 mm
Eye piece plus erector	16.223010 mm

4.0 Optical design of telescopic sight

As the targets are at short ranges, short focal length is considered for objective. Moderate focal lengths are considered for erector and eyepiece to restrict the vertex to vertex length of telescopic sight to within 250+-10mm.The aperture stop is considered in between two doublet erector for two reasons One being to obtain large eye relief and the second one for minimum deviation of CG of optical elements in telescopic sight from center of optical path . Readily available and low cost optical glasses are considered in the optical design of telescopic sight. Low density for optical glasses is also given weight age to reduce the weight of the telescopic sight optics[1-3].

4.1 Aberration corrections of telescopic sight

4.1.1 Optical design of objective

A cemented doublet covers only 5 degrees field – of – view. Closely spaced triplet lens with an aperture stop in front or behind or a Petzval lens is a conventional choice for field angles above 5 degrees. They increase the number of elements as well as weight of the objective an alternate novel configuration is worked out with a single element and a cemented doublet for objective. The Petzval sum of objective depends on refractive index difference of optical elements and individual powers of elements in the objective. It is independent of shapes of lenses in the objective. A proper balance of Petzval sum is obtained with appropriate powers for individual powers and index differences. The selection of powers and index differences for lenses in objective contributed 0.001438 mm Petzval sum by single element and 0.005589mm by cemented doublet which are in desired limits.. . The minimum Petzval contribution of objective may result for minimum astigmatism of objective during bending of lenses in objective. The bending technique vis implemented and brought longitudinal spherical aberration, OSC,

astigmatism. The optical glass selection and powers of lenses contribute for minimum longitudinal chromatic aberration and lateral color. The efforts are not made to reduce the distortion as the reticle design balances the residual distortion[4-8]. The Seidel aberrations of objective including reticle in 0.4 µm - 0.7 µm wave length range is give I Table3.

Table 3: Seidel aberrations of objective including reticle in 0.4 µm - 0.7 µm wave length range

S NO	SAB	OSC	AST	DIST	AC	TC	PTZ
1	0.065678	0.002735	0.760616	0.019189	0.429916	0.017902	0.002903
2	0.000700	0.000076	0.055840	-0.001389	-0.078826	-0.086150	-0.001465
3	0.330017	0.011599	2.722955	0.054248	0.803974	0.028257	0.006560
4	-0.768575	-0.018797	-3.070895	-0.037327	-2.097395	-0.051301	-0.000547
5	0.359579	0.005335	0.528327	0.003741	1.015743	0.015061	-0.000427
6	-0.006432	-0.000103	-0.010943	-0.000087	-0.016104	-0.000257	0.000000
7	0.000041	0.000000	0.000071	0.000000	0.000104	0.0000002	0.000000
SUM	+0.018732	+0.000846	+0.985972	+0.037776	+0.057411	+0.001048	+0.007025

4.1.2 Erector

The erector is configured with two cemented doublets with aperture stop in between. The focal length of erector is 38.89188 mm

4.1.3 Eyepiece

The eyepiece is configured with two cemented doublets with a focal length of 30.001300mm.

Aberration corrections of erector and eye piece

The erector and eye piece are designed separately for minimum on – axis and off- axis aberrations. The Seidel values qualified the systems for Petzval sum and two color aberrations. They are improved for coma and astigmatism using bending technique. The actual aberrations are calculated by trigonometric ray trace .Bending and optical glassy substitutions are implemented for satisfactory solution for aberrations of these systems The corrected erector and eyepiece are combined into a single system and again corrected for aberrations of the combined system. The Seidel aberrations of erector and eyepiece combination are shown in

Table4.The optical characteristics, optical configuration and optical design data of telescopic sight are shown in Table5, figure 2and Table 6 respectively..

Table 4: Seidel aberrations of Eye piece plus erector from Eye piece end in 0.4 µm - 0.7 µm wave length range

S NO	SAB	OSC	AST	DIST	AC	TC	PTZ
1	0.000696	0.000280	0.183150	0.067884	0.047974	0.0193000	0.005552
2	-0.002047	-0.000444	-0.156824	-0.021467	-0.078557	-0.070520	-0.001471
3	0.038100	0.002222	0.210692	0.013723	0.069685	0.004064	0.009350
4	0.000143	-0.000147	-0.246322	0.007007	0.007166	0.007379	0.009350
5	-0.012516	-0.001368	-0.243136	-0.015527	-0.097886	-0.010700	-0.014740
6	0.026315	0.001261	0.098177	0.003892	0.093426	0.004475	0.002313
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	1.063056	-0.006289	0.064093	-0.001319	0.787503	-0.004659	0.013860
9	-1.766139	0.026746	-0.658541	0.006024	-0.121362	0.016982	-0.004930
10	0.836680	-0.027892	1.511697	-0.030561	0.336055	-0.011203	0.011577
11	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
12	0.002370	-0.000507	-0.171698	0.015844	0.031493	0.006647	0.011577
13	-0.250844	-0.005574	-0.201346	-0.003759	-0.314976	-0.006999	-0.004930
14	0.433068	0.002814	0.029757	0.001411	0.293313	0.001906	0.014552
SUM	+0.363854	-0.008891	+0.416079	0.043152	0.053835	0.010142	0.065324

Table 5(a): optical characteristics of telescopic sight

Parameter	Value
wave length range	0.4 µm - 0.7 µm
Magnification	4.7X
Entrance pupil Diameter	28.2 mm
Exit pupil Diameter	6.0 mm

Field –of view	7.5 Degrees
Apparent field	36.0 Degrees
Focal length	∞
Back Focal length	∞
Entrance pupil Distance	-45.00 mm
Exit pupil distance	+42.82 mm
Vertex to Vertex Length	258.3 mm
Number of lance	011
Number of optical glasses	04
Reticle	In the objective image plane

Table 5(b): optical characteristics of telescopic sight

Lens system	Entrance pupil Distance	Exit pupil distance
Objective	-230.1416 mm	62.665910
Eye piece plus erector	+31.43286 mm	+44.85638

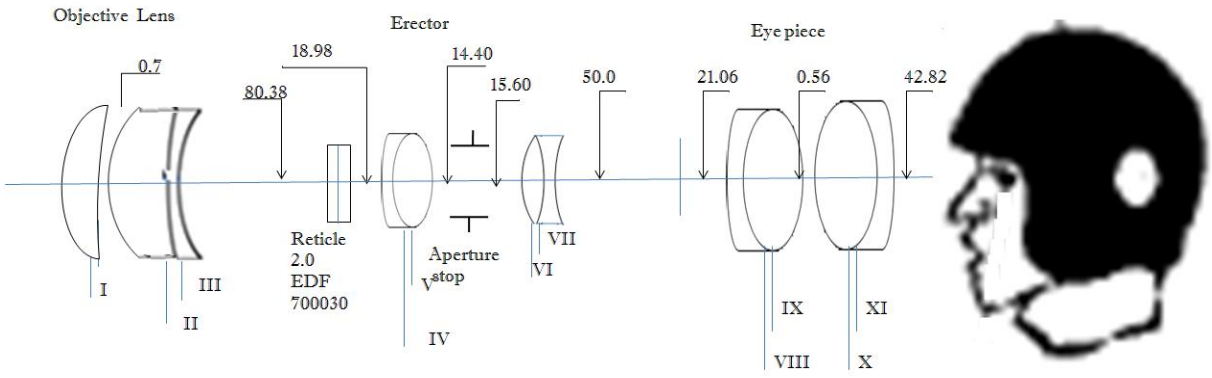

Figure 2: optical characteristics of telescopic sight

Table 6(a): optical design data of telescopic sight

LENS	GLASS	R1	R2	R3	R4	R5	CT	CA
I	DBC 613568	130.0 VEX	259..3 CAV				6.1	32.0
II	DBC 613568			57.89 VEX	58.71 CAV		9.6	32.0
III	EDF 700303				58.71 VEX	965.0 CAV	4.3	32.0

CT= Centre thickness, CA= clear aperture

ALL THE DIMENSIONS ARE IN MM

Table 6(b): optical design data of telescopic sight

LENS	GLASS	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	CμT	CA
IV	EDF 700303	28.4 VEX	12.65 CAV											2.3	18.0
V	LBC 541595		12.65 VEX	30.31 VEX										11.4	18.0
VI	LBC 541595				30.31 VEX	12.65 VEX								11.4	18.0
VII	EDF 700303					12.65 CAV	29.82 CAV							2.3	18.0
VIII	EDF 700303							178.67 VEX	33.0 CAV					2.23	32.0
IX	BaLF51 574521								33.0 VEX	39.0 VEX				9.45	32.0
X	BaLF51 574521										39.0 VEX	33.0 VEX		9.45	32.0
XI	EDF 700303											33.0 CAV	74.45 VEX	2.23	32.0

CT= Centre thickness, CA= clear aperture

ALL THE DIMENSIONS ARE IN MM

5.0 CONCLUSIONS

A nine element telescopic sight is designed for mounting on soldier rifle. The telescopic sight consists of objective, erector and an eyepiece. The magnification, field- of – view entrance pupil

diameter and exit pupil diameter of the optics are 4.7x, 15.0 degrees, 28.2 mm, 6.0mm respectively. The vertex to vertex length of the telescopic sight is 258.3. The telescopic sight is designed using only four optical glasses in nine elements. The telescopic sight images 50 -300 meter distant military targets in objective image plane which is reimaged by erector lenses in the object plane of eyepiece. Soldier sees the images of distant targets through an eyepiece from a distance equal to the eye relief of 42.82mm.The eleven lenses of telescopic sight uses only twelve different radii of curvatures. All the optical surfaces of telescopic sight are spherical. The optical design is unique in its optical characteristics and I have not come across design of this kind for comparison.

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