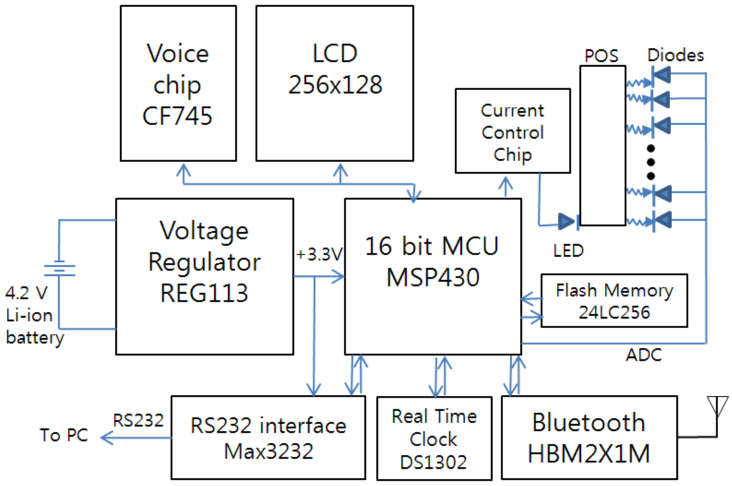
Supporting information on optical spectrum of LEDs

1. Detailed design and fabrication of the pocket-sized colorimetric reader

Colorimetric bioassay, detachable optical window, detachable holders for catridge, graphic LCD display with a resolution of 256x128, and a speaker for the blind are also shown in Fig. S-1. The picture shows the fully constructed instrument and a paper dipsticks on a holder. The whole unit is battery-operated at 3.3 volts using a 4.2 volt Li-ion rechargable battery with a 16 bit microcontroller and universal peripheral electronic components assembled on a custom-made printed circuit board. The reader provides a pop-up mechanism for loading the test strip on the cartridge holder using return spring.

Functions are implemented that allow for telecommunications with a PC or a smart phone, Bluetooth and USB communications, and tthe management of user data. Using a Bluetooth chip (HBM2x1M), the system provides serial commnunication service to a smart phone through the laboratory-made communication protocol. Cell phone supports the Bluetooth communication module usually. A USB2 serial chip (CP2102) is also included in order to communicate between the reader and a PC. To help the blind, a measurement-results-speaking service is implemented using a voice-generating chip (ISD2560), a voice-controlling chip (MCU CF 745), and a speaker. After receiving the data from the pocket system, a smart phone (Omnia 2, Samsung co., Korea), which runs on Window Mobile 6.0, sends the measurement data to a server system through the wireless communication network. The expert can get into the server system to care for the patinet continuously and quickly by replying to the smart phone of the users with information on proper medical care.

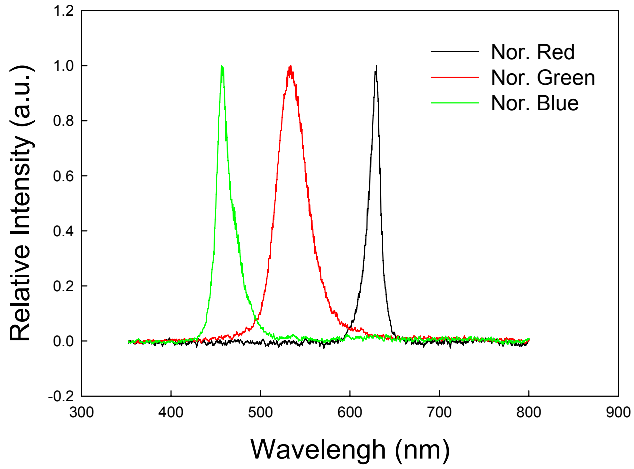
Fig. S-1



2. Optical spectrum of the tri-chromatic LEDs

Optical characteristics of the tri-chromatic LED light source measured at 25 °C and forward current value of 25 mA/chip using a miniature fiber optic spectrometer (USB2000, Ocean Optics, USA) is shown in Fig. S-2. It shows the tri-chromatic LED lights (R, G, and B) from a white LED module (SFT825N-S, Seoul Semiconductor, Korea), without inference. SPD (S5493-01, Hamamatsu co. Japan) has a spectral response in the visible range of from 350 nm to 100 nm without filter. The tri-chromatic LEDs have each inherent spectral colors with different center wavelengths (460 nm (blue color), 530 nm (green color), and 625 nm (red color)).

Fig. S-2



3. Optical output efficiency

Optical Ouput Efficiency was estimated with the sum of POS channel output over LED output as shown in Equation (1). POS channel output and LED output was measured with 3.3 inch Integrating Sphere to cover widely diverging output, with detecting methods as shown in Fig. S-3.

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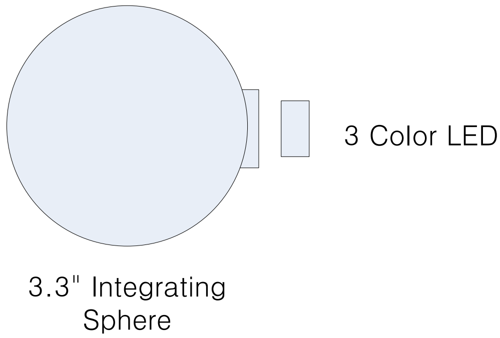
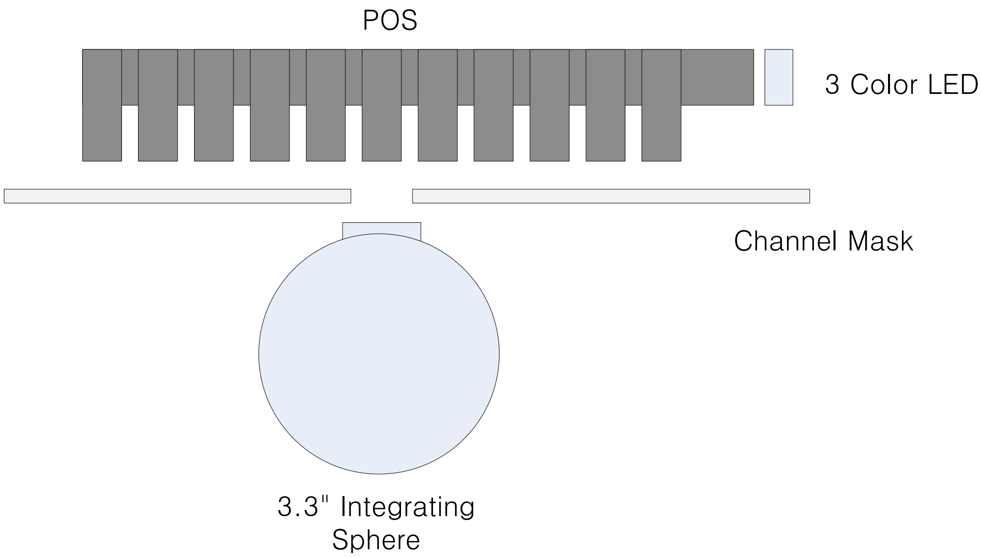
$$E = \frac{\sum (\text{POS channel output})}{\text{LED output}} \quad (1)$$

Fig. S-3



(a) Optical output of 3 Color LED was measured with 3.3" Integrating Sphere.



(b) Optical output of each POS channel was measured with channel mask and Integrating Sphere .

4. Preparation of standard solutions in artificial urine

We made preparations of an artificial urine solution as reported by Brooks and Keevil as follows.1 The artificial urine solution contined 1.1 mM lactic acid, 2.0 mM citric acid, 25 mM sodium bicarbonate, 170 mM urea, 2.5mM calcium chloride, 90 mM sodium chloride, 2.0 mM magnesium sulfate, 10 mM sodium sulfate, 7.0 mM potassium dihydrogen phosphate, 7.0 mM dipotassium hydrogen phospahte, and 25 mMm ammonium chloride all mixed in Deionized water. The pH of the solution was adjusted to 6.0 by addition of 1.0 M hydrochloric acid. All reagents were obtained from Sigma-Aldrich. Starting solutions containing the desired concentrations of glucose, albumin, RBCs, and WBCs were prepared using the artificial urine. The starting solutions were diluted to the desired concentrations of each analyte.

4. Choice of Biological Fluid, Self Calibration Method and Characterization

We concentrate on urine because it is the most informative physiological fluid that can be obtained noninvasively. Urinalysis using urine test strips is one of most powerful screening tests of renal and urinary tract related diseases. [2-4] Obviously, automated reading has analytical and clinical advantages over visual reading.[5] We used two kinds of urine samples. One test featured artificial urine samples spiked with standard solution for making standard curves. The other sample was one thousand human urine samples; this material were the fresh, noncentrifuged, well-mixed urine samples collected for routine urinalysis at the Department of Laboratory Medicine in Eulji University Hospital. As a sensor, 10-parameter urine test strips (Uriscan 10 SGL, YD diagnostics, Korea) were utilized.

The pocket system includes a self-calibration function. First, initial source light corrections are carried out using a white lid in the system when the system is on. Second, the effect of original urine color on the assays results is eliminated by a background-correction. We calibrated the pocket urinalysis system with artificial urine samples spiked with known concentrations of analytes.[6] The data were curve-fitted into the governing equations for simple quantifications by using SigmaPlot 10.0 software. We compared the semi-quantification ability of the pocket system with that of the ten-parameter test instrument (URiSCAN Pro Ⅱ, YD Diagnostics, Korea). Quantification comparisons for glucose and protein measured between the pocket system and the quantitative laboratory test instrument, (ADVIA 1650, Siemens Healthcare Diagnostics Solutions, USA) were attempted.[7] The microscopic results are compared with the RBCs and WBC grades from the pocket system.

5. Assay methods

We dipped the test dipsticks for the 10-parameters analysis into a plastic bottle (5 mL) of artificial urine for two seconds. We put the strip on its side for 1~2 second to remove excess urine and held the strip in a horizontal position to prevent possible mixing of chemicals from adjacent test areas. After 60 seconds, all test results were read by using the pocket-sized urinalysis reader.

For each analyte, the assay method is different. -For glucose, the assay is based on the specific glucose-oxidase/peroxidase reaction, i.e. the oxidation of glucose to gluconic acid and hydrogen peroxide catalyzed by glucose oxidase (GOD) and the following reduction of hydrogen peroxide and oxidation of potassium iodide to iodide catalyzed by peroxidase. The associated change in color from colorless to brown (I^- to I_2) indicates the presence of glucose.[8] As for protein, which is an important parameter in the identification of suspected kidney disease, the assay is based on the nonspecific binding of tetrabromophenol blue (TBPB) to albumins. TBPB binds to proteins through a combination of electrostatic (sulfonate) and hydrophobic (biaryl quinine methide) interactions.[9] When these compounds are bound, the phenol in TBPB is deprotonated and the color of the dye changes from yellow to green.[10]

For red blood cells, the test is based on the peroxidase-like activity of hemoglobin, which catalyzes the reaction of organic hydroperoxide and tetramethylbenzidine (TMB). The resulting color shifts from yellow to greenish blue. As for white blood cells, the test is based on the idea that the granulocytic leucocytes contain esterases that catalyze the hydrolysis of the derivatized pyrrole amino acid ester to liberate 3-hydroxy-5-phenyl pyrrole; this pyrrole reacts with a diazonium salt to produce a red-purple product. For other compounds, specific reactions methods were employed.[11] Basically, the colorimetric assays are ideal as simple diagnostic tests. They are stable and give visual readout. The reagents are less expensive than those for antibodies-antigens.

6. Day to day precision results by UriSCAN pro II and Healthy-100

(A) by URiSCAN pro II and Healthy-100 using URitrol I

Date	Instrument	pH	SG	Nitrite	Ketone	Bilirubin	Urobilin-ogen	Glucose	Protein	RBC	WBC
		5.0~7.0	1.010 ~1.030	-	-	-	±~1+	-	-	-	-
Day 1	Health-100	5.0	1.027	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.025	-	-	-	±	-	-	-	-
Day 2	Health-100	5.0	1.026	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.025	-	-	-	±	-	-	-	-

Day 3	Health-100	5.0	1.025	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.025	-	-	-	±	-	-	-	-
Day 4	Health-100	5.0	1.026	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.030	-	-	-	±	-	-	-	-
Day 5	Health-100	5.0	1.026	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.030	-	-	-	±	-	-	-	-
Day 6	Health-100	5.0	1.028	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.020	-	-	-	±	-	-	-	-
Day 7	Health-100	5.0	1.027	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.025	-	-	-	±	-	-	-	-
Day 8	Health-100	5.0	1.025	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.030	-	-	-	±	-	-	-	-
Day 9	Health-100	5.0	1.026	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.030	-	-	-	±	-	-	-	-
Day 10	Health-100	5.0	1.026	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.025	-	-	-	±	-	-	-	-
Day 11	Health-100	5.0	1.027	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.026	-	-	-	±	-	-	-	-
Day 12	Health-100	5.0	1.028	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.027	-	-	-	±	-	-	-	-
Day 13	Health-100	5.0	1.027	-	-	-	±	-	-	-	-
	URiSCAN	5.0	1.025	-	-	-	±	-	-	-	-
Day 14	Health-100	5.0	1.026	-	-	-	±	-	-	-	-

	URiSCAN	5.0	1.025	-	-	-	±	-	-	-	-

(B) by URiSCAN pro II and Health-100 using URitrol II

Date	Instrument	pH	SG	Nitrite	Ketone	Bilirubin	Urobilin-ogen	Glucose	Protein	RBC	WBC
		5.0~7.0	1.010 ~1.030	-	-	-	±~1+	-	-	-	-
Day 1	Health-100	7.6	1.003	+	2+	-	±	3+	-	2+	3+
	URiSCAN	6.5	1.010	+	3+	-	±	4+	-	3+	3+
Day 2	Health-100	7.6	1.003	+	2+	-	±	3+	-	2+	3+
	URiSCAN	7.5	1.010	+	3+	-	±	4+	-	3+	3+
Day 3	Health-100	7.4	1.004	+	2+	-	±	3+	-	2+	3+
	URiSCAN	7.5	1.005	+	2+	-	±	2+	-	3+	3+
Day 4	Health-100	7.5	1.005	+	2+	-	±	3+	-	2+	3+
	URiSCAN	7.5	1.010	+	3+	-	±	3+	-	3+	3+
Day 5	Health-100	7.5	1.005	+	2+	-	±	3+	-	2+	3+
	URiSCAN	7.5	1.010	+	2+	-	±	3+	-	3+	3+
Day 6	Health-100	7.6	1.005	+	2+	-	±	3+	-	2+	3+
	URiSCAN	8.0	1.015	+	3+	-	±	4+	-	3+	3+
Day 7	Health-100	7.5	1.004	+	2+	-	±	3+	-	2+	3+
	URiSCAN	7.5	1.010	+	2+	-	±	3+	-	3+	3+
Day 8	Health-100	7.6	1.004	+	2+	-	±	3+	-	2+	3+
	URiSCAN	7.5	1.010	+	3+	-	±	4+	-	3+	3+
Day 9	Health-100	7.5	1.005	+	2+	-	±	3+	-	2+	3+
	URiSCAN	8.0	1.015	+	3+	-	±	3+	-	3+	3+
Day 10	Health-100	7.5	1.005	+	2+	-	±	3+	-	2+	3+

	URiSCAN	7.5	1.010	+	2+	-	±	2+	-	3+	3+
Day 11	Health-100	7.5	1.004	+	2+	-	±	3+	-	2+	3+
	URiSCAN	7.5	1.010	+	2+	-	±	2+	-	3+	3+
Day 12	Health-100	7.6	1.004	+	2+	-	±	3+	-	2+	3+
	URiSCAN	8.0	1.005	+	3+	-	±	2+	-	3+	3+
Day 13	Health-100	7.5	1.005	+	2+	-	±	4+	-	2+	3+
	URiSCAN	7.0	1.010	+	2+	-	±	3+	-	3+	3+
Day 14	Health-100	7.6	1.003	+	3+	-	±	3+	-	2+	3+
	URiSCAN	8.0	1.010	+	3+	-	±	3+	-	3+	3+

(C) by URiSCAN pro II and Health-100 using URitrol III

Date	Instrument	Bilirubin	Protein
		1+~3+	2+~4+
Day 1	Health-100	2+	2+
	URiSCAN proII	3+	4+
Day 2	Health-100	1+	2+
	URiSCAN proII	3+	4+
Day 3	Health-100	-	4+
	URiSCAN proII	3+	4+
Day 4	Health-100	3+	4+
	URiSCAN proII	3+	4+
Day 5	Health-100	-	4+
	URiSCAN proII	3+	4+
Day 6	Health-100	-	4+
	URiSCAN proII	3+	4+
Day 7	Health-100	-	4+
	URiSCAN proII	3+	4+
Day 8	Health-100	2+	4+
	URiSCAN proII	3+	4+

Day 9	Health-100	1+	4+
	URiSCAN proII	3+	4+
Day 10	Health-100	2+	4+
	URiSCAN proII	3+	4+
Day 11	Health-100	3+	2+
	URiSCAN proII	3+	4+
Day 12	Health-100	3+	4+
	URiSCAN proII	3+	4+
Day 13	Health-100	1+	4+
	URiSCAN proII	3+	4+
Day 14	Health-100	-	2+
	URiSCAN proII	3+	4+

7. Comparison of Health-100 vs. URiSCAN pro II

(A) pH (n=1000)

	Health-100									
URiSCAN pro II	9.0	8.5-8.9	8.0-8.4	7.5-7.9	7.0-7.4	6.5-6.9	6.0-6.4	5.5-5.9	5.0-5.4	Total
9.0	1									1
8.5		6	1							7
8.0		1	13	23						37
7.5		1		31	28					60
7.0					55	4				59
6.5					9	81	17			107
6.0						11	64			75
5.5							117	61	3	181
≤5.0							18	188	267	473
Total	1	8	14	54	92	96	216	249	270	1,000
% agreement (exactly match)										57.9 %
% agreement (± 1 color block)										98.1 %

(B) specific gravity (n=1000)

URiSCAN pro II	Health-100							
	1.030	1.025 1.029	1.020 1.024	1.015 1.019	1.010 1.014	1.005 1.009	1.000 1.004	Total
-1.030	12	232	3					247
1.025 - 1.029		159	48					207
1.020 - 1.024		15	149	8		2		174
1.015 - 1.019			92	111	17	3		223
1.010 - 1.005				55	55	16		126
≤1.005					3	17	3	23
Total	12	406	292	174	75	38	3	1,000
% agreement (exactly match)								50.3%
% agreement (± 1 color block)								99.2%

(C) Ketone (n=1000)

URiSCAN pro II	Health-100					
	3+	2+	1+	Trace	Negative	Total
3+	1	7				8
2+		12	2			14
1+	1	14	4	3		22
Trace		14	12	13	1	40
Negative	3	4	17	27	865	916
Total	5	51	35	43	866	1,000
% agreement (exactly match)						89.5%
% agreement (± 1 color block)						96.1%

(D) Bilirubin (n=1000)

URiSCAN pro II	Health-100					
	3+	2+	1+	Trace	Negative	Total
3+						
2+	3					3
1+		1	2			3
Trace						
Negative		1	61		932	994
Total	3	2	63		932	1,000
% agreement (exactly match)						93.4%
% agreement (± 1 color block)						93.8%

(E) Urobilinogen (n=1000)

URiSCAN pro II	Health-100				
	3+	2+	1+	Trace	Total
3+	2				2
2+		6			6
1+			6		6
Trace			84	902	986
Total	2	6	90	902	1000
% agreement (exactly match)					91.6%
% agreement (± 1 color block)					100%

(F) Nitrite (n=1000)

URiSCAN pro II	Health-100			
	Positive	Trace	Negative	Total

Positive	31			31
Negative		3	969	969
total	31	3	969	1000
% agreement (exactly match)				99.7%
% agreement (± 1 color block)				100.0%

(G) Protein (n=1000)

	Health-100						
URiSCAN pro II	4+	3+	2+	1+	Trace	Negative	Total
4+	9	12	5				26
3+			7		1		8
2+		15	38	11			64
1+				15	21	3	39
Trace				5	50	10	65
Negative				1	58	739	798
Total	9	27	60	32	130	752	1000
% agreement (exactly match)							85.1%
% agreement (± 1 color block)							99%

(H) Glucose (n=1000)

	Health-100						
URiSCAN pro II	4+	3+	2+	1+	Trace	Negative	Total
4+	18	3	3				24
3+		4	2				6
2+		1	12	1	1	1	16

1+			3	5	3	1	12
Trace				2	8	19	29
Negative						913	913
Total	18	8	20	8	12	934	1000
% agreement (exactly match)							96.0%
% agreement (± 1 color block)							99.4%

(I) RBC (n=1000)

	Health-100				
URiSCAN pro II	3+	2+	1+	Negative	Total
3+	47	44	2		93
2+		8	74	3	85
1+			47	28	75
Trace			22	71	93
Negative			6	648	654
Total	47	52	151	750	1000
% agreement (exactly match)					75.0%
% agreement (± 1 color block)					96.1%

(J) WBC (n=1000)

	Health-100				
URiSCAN pro II	3+	2+	1+	Negative	Total
3+	30	11			41
2+	4	32	4		40
1+		10	40	11	61
Trace		1	23	30	54
Negative		2	36	766	804

Total	34	56	103	807	1000
% agreement (exactly match)					86.8%
% agreement (± 1 color block)					95.0%

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